THE UNITED STATES
STRATEGIC BOMBING SURVEY

THE ELECTRIC POWER INDUSTRY OF JAPAN

(Plant Reports)

Electric Power Division

May 1947

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This report was written primarily for the use of the U. S. Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

FOREWORD

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt. Its mission was to conduct an impartial and expert study of the effects of our aerial attack on Germany, to be used in connection with air attacks on Japan and to establish a basis for evaluating the importance and potentialities of air power as an instrument of military strategy for planning the future development of the United States armed forces and for determining future economic policies with respect to the national defense. A summary report and some 200 supporting reports containing the findings of the Survey in Germany have been published.

On 15 August 1945, President Truman requested that the Survey conduct a similar study of the effects of all types of air attack in the war against Japan, submitting reports in duplicate to the Secretary of War and to the Secretary of the Navy. The officers of the Survey during its Japanese phase were:

Franklin D'Olier, *Chairman.*
Paul H. Nitze, Henry C. Alexander, *Vice Chairmen.*
Harry L. Bowman,
J. Kenneth Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Fred Searls, Jr.,
Monroe E. Spaght,
Dr. Lewis R. Thompson,
Theodore P. Wright, *Directors.*
Walter Wilds, *Secretary.*

The Survey's complement provided for 300 civilians, 350 officers, and 500 enlisted men. The military segment of the organization was drawn from the Army to the extent of 60 percent, and from Navy to the extent of 40 percent. Both the Army and the Navy gave the Survey all possible assistance in furnishing men, supplies, transport, and information. The Survey operated from headquarters established in Tokyo early in September 1945, with subheadquarters in Nagoya, Osaka, Hiroshima, and Nagasaki, and with mobile teams operating in other parts of Japan, the islands of the Pacific, and the Asiatic mainland.

It was possible to reconstruct much of wartime Japanese military planning and execution, engagement by engagement, and campaign by campaign, and to secure reasonably accurate statistics on Japan's economy and war production, plant by plant, and industry by industry. In addition, studies were conducted on Japan's over-all strategic plans and the background of her entry into the war, the internal discussions and negotiations leading to her acceptance of unconditional surrender, the course of health and morale among the civilian population, the effectiveness of the Japanese civilian defense organization, and the effects of the atomic bombs. Separate reports will be issued covering each phase of the study.

The Survey interrogated more than 700 Japanese military, government, and industrial officials. It also recovered and translated many documents which not only have been useful to the Survey, but also will furnish data valuable for other studies. Arrangements have been made to turn over the Survey's files to the Central Intelligence Group, through which they will be available for further examination and distribution.

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SUBSTATIONS

1. The inspections of Japanese electric generating plants and facilities were undertaken by the Electric Power Division with the following objectives in view:

a. To determine the general condition and characteristics of the plants and their wartime operations and difficulties.

b. To study the effects of physical damage due to bombing where damage occurred and the results on production.

c. To estimate the results that might have been obtained if damage had been inflicted.

d. To obtain a measure of vulnerability and recuperability.

e. To secure data on actual bombing results and correlate it with intelligence assessment reports, as well as to evaluate intelligence information.

f. To secure such other facts as might be pertinent to the Survey.

In order that all the plant reports might be made in an orderly manner, with the essential subject matter covered, all reports followed a definite outline, which follows this summary.

2. Japan's generating plants are, with only very minor exceptions, of two types, namely, thermal (steam) and hydro. All the steam plants use coal as fuel. It is obtained principally from the islands of Hokkaido and Kyushu and has heat values ranging from approximately 7,500 to 10,500 Btu. The hydro plants are principally run-of-river type, as the recurrence of earthquakes and the porous volcanic type of soil preclude the possibility of maintaining large concrete storage dams. There is, however, some storage. It is principally natural, but there is also some artificial storage as the result of dams which are primarily used for diversion but act as storage as well.

3. All types of plants and conditions were studied in order to secure a comprehensive cross section. Steam plants in the Tokyo, Nagoya, Osaka, and Kure areas were surveyed. Hydro plants in a number of locations were visited, but, in particular, plants on two complete river developments, namely, the Hida River and the Kiso River, were studied. In addition, numerous key primary transformer and switching stations and secondary substations, as well as other vital equipment or strategic points, were thoroughly covered.

4. A total of 13 steam plants, 24 hydro plants, 16 primary (or transmission) substations, and 21 secondary (or distribution) substations were visited. Of these, 8 steam plants, 1 hydro plant, 9 primary and 21 secondary substations had been damaged. The total government-licensed available capacity of the steam plants visited was 1,589,500 KW or 51 percent of the capacity of public utility steam generating plants, including railways, in all Japan. These steam plants generated 2.4 billion KWH in 1943 or 40 percent of all steam generation. The total government-licensed available capacity of the hydro plants visited was 633,150 KW or 11 percent of the capacity of public utility hydro generating plants, including railways, in all Japan. These hydro stations generated 2.7 billion KWH in 1943 or 9.5 percent of all hydro generation. All the generating plants (combined steam and hydro) visited had a total capacity of 2,224,650 KW or 25 per cent of the capacity of all plants and generated 5.1 billion KWH in 1943 or 14.8 percent of all generation. Japan does not have large hydro plants but a great number of smaller ones; therefore, though the number of hydro plants visited does not reflect a large percentage of the total, they are very representative of the type of plant that is found throughout the country. The substations visited totaled 2,111,900 KVA in transformer capacity or 11.9 percent of the total for all Japan. However, the amount of transformer capacity does not always reflect the true importance of a substation, as often the switching and control effected are the real reason for its existence, and the amount of transformed current is only a fractional part of the current that actually passes through the station.

5. A consolidated list of the plants visited together with report number, size, generation, and a statement as to whether the station was damaged, follows:

Steam-Electric Generating Plants

Report No.	Name of plant	Capacity (1,000 KW) Govt. licensed	Capacity (1,000 KW) Name-plate	Generated 1943 (million KWH)	Bombed
	KURE-HIROSHIMA AREA:				
1	Saka	64.2	73.75	207	No.
	NAGOYA AREA:				
2	Meiko	138	159	286	Yes.
3	Nagoya	129	144	116	Yes.
	OSAKA AREA:				
4	Amagasaki No. 1	318	318	522	Yes.
5	Amagasaki No. 2	300	300	660	Yes.
6	Amagasaki East	147	148	134	No.
7	Kasugade No. 1	50	50.5	10	No.
8	Kasugade No. 2	65	65	45	Yes.
	TOKYO AREA:				
9	Kawasaki	55.3	71.5	103	Yes.
10	Senju	77.5	77.5	73	No.
11	Tsurumi	178.5	178.5	146	Yes.
12	Ushioda	64	77	100	Yes.
	Nagasaki (separate report)	3	3		Yes.
	Total steam	1,589.5	1,665.75	2,402	

Report No.	Name of plant	Capacity (1,000 KW) Gov't licensed	Capacity (1,000 KW) Name-plate	Generated 1943 (million KWH)	Bombed
13	Shimotaki	36.5	36.8	124	No.
14	HIDA RIVER PLANTS				
	Osaka	18	16	112	No.
	Seto	18	19	265	No.
	Shimohara	22	21	105	No.
	Ofunata	6.1	6.1	22	No.
	Shichiso	6.15	6	36	No.
	Nagura	22.2	20	110	No.
	Kamiazo	27	24.3	163	No.
	Kawabe	30	26.1	109	No.
	Imawatari	20	20	96	No.
15	KISO RIVER PLANTS:				No.
	Miura (new 1945)	7.5	7.5		No.
	Ontake (new 1945)	22	22		
	Tokiwa	14.6	13.6	51	No.
	Nezame	35	32	114	No.
	Momoyama	24.6	24	150	No.
	Suhara	10	9.2	56	No.
	Okuwa	12.1	12	80	No.
	Yomikaki	42.1	40.8	254	No.
	Shizumo	16.3	15	114	No.
	Ochiai	14.7	14.4	62	No.
	Oi	18	44	188	No.
	Kasagi	40.5	36	130	No.
	Kaneyama	37.1	37.2	[1]21	No.
16	Saku	[2]72.7	67.2	351	Yes.
	Total hydro	633.15	600.8	2,746	

[1]New plant, operated only a portion of 1943. This plant generated 121 million KWH in 1944.

[2]This is the rating carried on Japanese records, although one 6,750-KW unit was removed in July 1945. Name plate rating given is for generators actually in the plant in November 1945. Licensed rating should be approximately 66,000 KW in accord with present equipment and maximum output.

6. There were no visits to plants or other facilities in Formosa, Korea, or Manchuria. These areas were not, in any way, physically connected with the main Japanese Islands, and therefore were totally independent in their operation. After careful consideration based on information received in Japan, it was decided that a physical survey in these locations was not practical because of the time element and the military situation involved.

7. While the survey of these plants was not for the purpose of studying Japanese engineering practices, they would, of course, be an operating factor and, therefore, a part of wartime operation. While some of the equipment is modern, it was evident that the Japanese did not possess the ability to utilize efficient methods or, of themselves, to devise new and better means of accomplishing desired results. It is a known fact that foreign engineering firms, engineers, and technicians designed and installed much of the equipment, and such Japanese equipment as exists shows irrefutable evidence of being purely a case of design copy. The absence of this foreign engineering assistance for the years just prior to and during the war is

Report No.	Name of plant	KVA in thousands	Bombed
17	NAGOYA AREA:		
	Inuyama (primary)	60	Yes.
	Iwakura (primary)	120	Strafed.
	Nisshin (primary)	150	No.
	Rokugo (secondary)	52	Yes.
	Taiko (secondary)	30	Yes.
18	Mie (primary)	100	Yes.
19	OSAKA AREA:		
	Dotombori	6	Yes.
	Nakamoto	6	Yes.
	Ishizugawa	28.2	Yes.
	Sakaigawa	7	Yes.
	Sakurajima	17.5	Yes.
	Yamatogawa	3	Yes.
20	Yao (primary)	300	Yes.
21	Shiojiri (primary)	60	No.
22	Kawasaki (primary)	210	Yes.
23	Tokyo (primary)		
	Hanabata	168	No.
	Hatogaya	168	No.
	Kameido	108	Yes.
	Keihoku	162	No.
	Komatsugawa	54	No.
	Wadabori	150	No.
24	Tokyo (secondary)		
	Chigasaki	11.5	Strafed.
	Hachoji	16.5	Yes.
	Honghicho	3	Yes.
	Jukkengawa	9	Yes.
	Kojimachi	6	Yes.
	Nippori	9	Yes.
	Oshima	12	Yes.
	Ozaku	7.5	Strafed.
	Sugamo	6	Yes.
	Hiroshima area: (separate report)		
	Dambara (secondary)	6	Yes.
	Otemachi (secondary)	6	Yes.
	Railway (secondary)	1.2	Yes.
	Nagasaki area: (separate report)		
	Industrial (secondary) (Size unknown—completely obliterated.)		Yes.
	Takekubo (primary)	24	Yes.
	Uragami (primary)	10.5	Yes.
	Zemza (primary)	24	Yes.
	Total capacity, substations	2,111.9	

clearly seen, and there were many instances of poor practice that would not have been tolerated in the United States. At no place was there any equipment of new or advanced design, and, as a matter of fact, there were many instances where equipment previously installed was either not utilized to its proper efficiency or had simply been abandoned. It is proven that, on the whole, the Japanese did not possess the technical "know how" to operate efficiently.

8. Steam plants were, in general, in a run-down condition. This was due, to some extent, to the lack of proper maintenance and materials and the effect of unusual conditions, such as poor coal. However, there is definitely the impression that it is simply poor housekeeping. There was, in the latter part

of the war, little incentive to maintain any high standards of maintenance; however, it is deplorable that so little effort has been made to safeguard costly equipment from the deteriorating effects of the elements. There was never any actual shut down of plants because of a lack of coal, but the reserves became at times so low that there was grave concern over the situation. The steam plants were designed to use coal of a certain heat value. During the war, the plants had to use a poorer grade of coal with resultant decreased capacity and higher maintenance.

9. Hydro plants were in far better condition than the steam plants. By its nature, a hydro plant is easier to maintain and is not subject to a large amount of deterioration or obsolescence. In general, the design of these plants was good. In two instances, a complete study was made of entire river developments, and the utilization of the natural resources of power supply was excellent. There were no serious operating difficulties during the war.

10. Transformer and switching stations were generally of good construction, though excess capacity seemed to prevail, as well as other factors not in keeping with usually accepted engineering practice. Over-all system operations are fully covered elsewhere, but examination of this group of stations revealed an unjustified multiplication of facilities, overcapacity, and poor operation.

11. Engineering data given in the plant reports are necessarily very brief and are only given in order to describe more adequately the type of plant, its essential components, or operation factors. Much additional engineering data and other information were secured. For practical reasons this information could not be reproduced in the reports but is available in the USSBS files.

12. All types of physical damage were found. In steam generating plants, the degree of damaged facilities definitely varied in proportion to the number of bomb hits, but, in general, the size of bombs and the type of fuzing used were not such as would produce the best damage results. It is understandable that the bombs that did the damage were not selected for use on this type of industrial target, as the bombing in each instance was merely incidental to attacks on adjacent targets or general area raids. However, it can be seen that the use of larger bombs with longer delay in the nose and tail fuzing (e. g., 1,000-lb. bombs fuzed 1/25 sec. nose and tail) would have produced much more serious damage. Power plants are in buildings usually 60 to 100 ft. in height, with the most vital equipment located near floor level. Therefore, the most destructive effects are secured when detonation occurs sufficiently long after the bomb passes through the roof to reach the major equipment. The destruction of, or serious damage to, such items as turbines, generators, boilers, and transformers rendered the plants inoperative for a year or more. The destruction of, or heavy damage to, associated switching equipment, electrical, boiler, and steam controls, coal-handling equipment, and water supply caused inoperative periods of months or weeks. Hydro damage was not sufficient to permit a study of the physical damage effects, but with the substitution of penstocks for boilers, the same outline of possible production loss would exist as was found in the steam plants. The damaged transformer and switching stations show that delayed action bombs are not essential, as these stations are mostly of the open-air type or are situated in low buildings; nor is as heavy a bomb required as is desirable in generating plants. Transformers are not, in themselves, a producing unit, and so loss of production cannot be measured, but the transformation of current is an essential in the delivery to the consumer of the end product of generating plants.

13. Actual effects from various types of weapons were found and studied for effectiveness. Of most interest, perhaps, were the effects on the electric facilities of the atom bomb in Nagasaki and Hiroshima. Reports on these two areas are made separately, and reference is made directly to those reports. In Japan, a large part of the bombing was done with incendiaries, and much opportunity was given to obtain first-hand information on what damage these caused to electric installations. The definite conclusion is that incendiaries produce no damage to power plants other than minor inconvenience by the destruction of wooden warehouses or employees' houses. Where substations were of inflammable construction or where they were located in the center of highly congested areas built of inflammable materials, they were destroyed along with the areas. This was mostly true of secondary substations. There was only one instance, and it might be regarded as a freak, where incendiary bombs were ever the direct cause of any equipment damage. Against this, are many instances where they fell directly on substations and did no damage. Therefore, where substations were of modern and fireproof construction and safeguards were taken against exposure to adjacent fire, incendiary bombs were not effective. Strafing produced considerable damage, but since this method of attack is only possible where air defense permits low-altitude

attack, it is not considered a practical means of destruction. There is one case of damage from rockets, but this type of weapon is subject to the same limitations as strafing. The highest degree of damage, the longest recuperability cycle, and the greatest amount of weapons' effectiveness were found where damage was caused by HE bombs. While power plants and substations were never primary bombing objectives, and, therefore, the HE bomb damage was done by types intended for use on other kinds of targets, the damage was sufficient to show conclusively that the HE bomb is by far the most effective weapon and produces the highest results with the least tonnage per acre. Proper size HE bambs and appropriate fuzing would have caused much greater damage.

14. These plant studies show emphatically the vulnerability of power plants, substations, and kindred installations. From the standpoint of location, steam plants are easily accessible, whereas hydro plants are not, although both are equally susceptible to damage. Further, a study of plant acreage shows that steam plants cover sufficiently large areas and are easily identified by their tall stacks or other easily discernible markings. In the final industry report, the general vulnerability of power plants is thoroughly discussed. These plant studies verify, by actual instances of shut-downs caused by destruction or damage to vital links in the cycle of operation, the fact that power plants have a high degree of vulnerability. They can be, and have been, put out of operation for long periods of time with a relatively small tonnage of bombs. Substations, as a rule, do not cover much acreage, but they are highly susceptible to bomb damage, and their vulnerability is limited only in respect to the accessibility of their location.

15. At no place in Japan had there been any concerted effort on repairs; therefore, the degree of recuperability must be based on assumptions founded on a knowledge of normal expectancy. Such recuperation as had been accomplished shows that the Japanese lacked ability to recover from the effects of sustained damage or to devise any particularly ingenious methods of substitution. This can be demonstrated by instances in which minor repairs, which would be handled elsewhere with speed, dispatch, and efficiency, required many hours because of their slowness and lack of organization. Where no repairs had been made and the period required for recuperation had to be estimated, this estimate was based on normal availability of equipment and labor. The estimated time is certainly less than it would have taken in Japan during the war because of the fact that a large portion of the electrical equipment manufacturing plants had been converted to the manufacture of other products and that skilled labor had been drafted into the armed forces.

16. In general, the intelligence data in the field of pre-raid description were very accurate and varied from the actual only in minor details. However, it did not evaluate the relative importance of various installations, and there was little emphasis on the results of any combined action against any group of electric utility targets. In practically every instance, data on actual bombings could be correlated with attacks on near-by targets, and there was no instance in which the power plant or substation visited was the subject of a specific attack against it. In reviewing the damage assessment reports, a definite lack of interpretation of damage to electric utility installations was noted.

17. It requires an over-all study to determine the results that would have been secured had the undamaged plants visited been the objectives of bombing. However, in each plant study, the production of that plant and any peculiar significance surrounding its particular position were viewed in order to determine its individual importance. In general, the bombing of any steam plant would have been desirable in view of the small effort required, whereas the opposite was true of hydro plants. In the case of substations, there was evidence that the destruction of any single substation would have produced no effect since there were adjacent substations and interconnection facilities whereby alternate means of preserving continuity of service could have quickly been put in operation. Only by elimination of these alternate means, accomplished by simultaneous destruction of a number of substations, could results have been achieved which would have effectively interrupted the flow of energy.

18. It was interesting to learn from the plant operators that the Japanese Government had, during the early part of the war, assured them so convincingly that it was impossible for them to be bombed, and then, later on, that plants would be given first priority in defense against attacks, and that no consideration had been given to plant protection or any plan for recuperation until very late in the war. It was only then that some bomb barriers and shelters for workmen were built, but the results achieved were negligible. There was some attempt made to disperse excess equipment to points of safety or central locations, but lack of transportation prevented carrying out this program to any appreciable degree. At a

number of substations, excess equipment had been dismantled but never even removed from the station area; therefore, the spares were destroyed along with the balance of the station, and thus, any possibility of quick recuperation was precluded.

19. It was proven that electric power facilities are very vulnerable. The generation, transmission, and distribution of electric energy to the ultimate consumer is a series of processes, the interruption of any one of which renders the whole inoperative. Electric energy cannot be stored. Its production and consumption must be simultaneous and continuous. The damage done to the plants and substations, while in itself of a paralyzing nature and producing production losses that would have had a most disastrous effect on the power industry, came at a time when severe losses were being sustained by industry, and therefore, the production loss caused by the damage did not have a disturbing economic effect.

20. The Electric Power Division arrived in Japan early in October 1945 and spent approximately 2 months there. Many field trips were made to secure the information contained in these reports. The following members carried the major responsibility:

Mr. W. E. Mitchell, Chief,
Maj. Robert L. Norton, A. C., Executive Officer,
Capt. Wiley W. Wolfe, A. C., Administrative Officer,
Col. James F. Davenport,
Lt. (jg) Herbert A. Deane, USNR,
Mr. Karl Enz,
Mr. William K. Fowler,
Mr. George Grimm,
Mr. Clarence A. Johnson,
Lt. (jg) William A. W. Krebs, Jr., USNR,
Mr. Fred W. Utz,
S/Sgt. Joe C. Ashby, A.C., Chief Clerk.

With the able assistance of other personnel as stenographers, photographers, interpreters, draftsmen, guides and drivers.

OUTLINE OF PLANT REPORTS

Summary.

1. Name of plant, location, size, principal features, yearly output, and function in enemy economy.
2. Attacks, dates, air force involved, tonnage dropped, and number of hits.
3. Principal physical damage, production loss, recuperability, and vulnerability.
4. Check on intelligence data.
5. Significant evaluations or impressions.

Detailed Report.

The plant and its function in enemy economy.

1. Product of plant and importance in enemy economy.

2. Physical description of plant.

a. Location, lay-out, shape, and acreage of plant area, principal buildings, special identifiable markings, general comments on design, construction, and engineering features.

b. Sources of fuel or any other vital factors in operation.

3. Ownership and management with names and positions of persons from whom information was secured.

4. Number of employees, shifts worked, seasonal conditions, or other particulars on labor.

Attacks.

Number of raids, air force involved, name of primary target, date and hour of attack, number, type, and fuzing of bombs dropped, number of aircraft, altitude, weather, and any other pertinent facts as obtained from target data. Number of bomb hits in area and on buildings or vital equipment as found from actual inspection.

Effects of bombing.

1. Physical damage.

a. Damage done to buildings, equipment, or facilities, giving cause, such as blast, shock, fragmentation, falling debris, fire, or weather, with information as to whether damage was due to direct hits, near misses, or indirect causes, such as exposure to adjacent fire. Comparison between the number and type of bombs hitting in the plant area, with the damage done, from which conclusions may be obtained on weapons' effectiveness. Brief description of protective measures and installations made and results of their use.

b. Bomb plot as an exhibit, reconstructed from actual facts and conditions seen or from information considered reliable obtained locally, where possible to produce.

2. Production loss.

a. Production—actual at time of damage or past wartime average, together with future planned, compared with actual attained after damage. Where recuperation was not made, production loss based on estimated period required for recovery, with consideration given to any partial production that has been or could be reattained.

b. Any substitution or modification possible.

c. Causes for loss of production.

(1) Physical damage to particular vital portions of plant.

(2) Diversion of labor, materials, or other facilities.

(3) Loss caused by emphasis on protective measures.

(4) Loss of production through absenteeism or unusual inefficiency.

(5) Loss caused by shortage of essentials, such as fuel, transportation, inability to distribute, or other causes, and whether this loss was caused by bombing or other factors.

3. Recuperability cycle.

a. Time required to restore production either from actual repairs made or estimates of time that will be required.

b. Level of production reattained.

c. Ability to utilize undamaged portion of plant.

4. Vulnerability.

a. Peculiar vulnerability of the physical plant installation as shown by actual damage, together with weak links, bottlenecks, or other pertinent factors, such as location, surroundings, or conditions affecting probable ability to inflict damage.

Intelligence check.

1. Information and source, importance of plant, identification and location, essential buildings or other data, and correctness thereof.

2. Damage assessment and photo interpretation made, as compared with actual conditions.

3. Photo interpretation of recuperation or dispersal as compared with actual conditions.

Data relevant to other studies.

Any information pertinent to or affecting any other division of the Survey.

Evaluations and impressions.

Any important or interesting facts or impressions gained from the study of the actual conditions.

SAKA STEAM POWER PLANT

NEAR HIROSHIMA, JAPAN

DATE INSPECTED 3 NOVEMBER 1945

Summary.

1. The Saka steam electric generating plant, located on Kaito Bay 4 miles SE of Hiroshima, had 73,750 KW installed generator capacity. It is located in two large reinforced concrete buildings with coal handling and storage equipment on one side. Its yearly output averaged approximately 188 million KWH during the 3 war years. It was the largest plant in the Kure-Hiroshima highly industrialized naval, arsenal and armament manufacturing area. The requirements of this district for electric energy were too great to be supplied by hydro power, even during the periods of ample water, and therefore this plant operated throughout the year and was very important.

2. The plant was never a primary target and was never directly damaged, though a surge on the line during a raid on Kure caused minor damage to a transformer bushing, and the atomic bomb on Hiroshima caused slight building damage.

3. There was not any loss of production due to damage, as it was quickly repaired. This plant was very vulnerable. Besides being susceptible to easy bomb damage as are all generating stations, this plant was easily located as it had a number of tall stacks, had no natural protection, and was situated on the edge of the bay.

4. The location of this plant was shown correctly in intelligence data, but its size and importance was not properly evaluated.

5. The ease with which serious damage could have been done to this plant seems very apparant, and the resultant effects would have had a serious effect on this industrial area.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The Saka steam electric generating plant is one of the important generating stations in the Kure-Hiroshima district which is a naval base, arsenal and armament manufacturing area. The energy was supplied to the integrated system of the Japan Electric Generation and Transmission Co. Prior to, and during the war, hydroelectric energy from Central Japan was never sufficient to supply the requirements of this region, even during the periods of ample water at the hydro stations. Therefore, the entire energy production of this plant was utilized in the very important military area in which it was located and was a vitally essential necessity.

The importance of this plant is clearly shown by the fact that it operated 7,692 hours in 1943 and 7,685 hours in 1944, both being out of a possible total of 8,784 hours per year. This is a very high percentage of operating hours in steam plants. The plant generated 207,169,308 KWH in 1943 and 185,237,422 KWH in 1944 with a peak of 54,930 KW in August 1943 and 55,484 in October 1944. The lowest monthly peak load during these 2 years was 35,900 KW occurring in April 1944. This high rate of production continued thru January and February 1945 when loss of load due to war damage caused its generation to fall off rapidly. Further statistics on plant operation are shown in Exhibit A.

2. Physical description of plant.

a. The plant is located on Kaito Bay approximately 4 miles SE of Hiroshima and 6 miles N of Kure. (Exhibit B). The plant area is an irregular triangle in shape covering approximately 15 acres. The main plant is in 2 reinforced concrete buildings each approximately 250 ft. square and 4 to 5 stories in height. One building has three concrete stacks about 200 feet in heighth and 4 short steel stacks while the other building has 3 short steel stacks. Both buildings and stacks are camouflaged with black and white paint. One building, known as Station No. 1, is in 2 sections. Section No. 1 was completed 17 December 1927 and contains four 330-psi, traveling-grate type B&W boilers each with maximum capacity of 90,000 lbs/hr and with individual steel stack. There are 2 Brown Boveri turbogenerator units each 12,500-KW, 60-cycle, 3-phase, 11,000-volt, 3,600-rpm. In addition, there is a separate Brown Boveri house turbogenerator of 1,550-KW capacity. Section 2 was completed 4 August 1935 and contains three 490-psi, pulverized coal B&W boilers each with maximum capacity of 160,000 lbs/hr and with individual concrete stacks. There is 1 Mitsubishi turbogenerator

unit rated 25,000-KW, 60-cycle, 3-phase, 11,000-volts, 3,600-rpm and with a direct connected house generator rated 1,200-KW, 60-cycles, 3,300-volt, 3,600-rpm. The other building known as Station No. 2 was completed 1 June 1941 and contains three 265-psi. traveling-grate type B&W boilers each with maximum capacity of 78,000 lbs hr and with individual steel stacks. There are 3 Ljungstrum type turbo-generators each rated 7,000-KW, 60-cycle, 3-phase, 11,000-volts, 3,600 rpm. Two of these units are Mitsubishi make and were transferred from the Yahagi generating station. The other unit was made by the Osaka Iron Works and was installed new. Both the buildings have an enclosed electrical bay containing transformers, bussing, switching, etc., but with an additional outdoor switching station. Adjacent to the plant is a coal storage and handling yard with wharf on the bay and unloading facilities for handling coal from boats. The total name plate capacity of the plant is 73,750 KW, which includes 2,750-KW in house generators. The plant is listed by the government and the owners as 64,200 KW capacity, and the peak load attained was 55,484 KW.

b. Coal is obtained from Kyushu normally by boat but can be brought in by rail. Heating value is 10,000 Btu, however, from 1942 to 1945, the quality of the coal had declined to 9,500 Btu. Although the plant did not shut down at any time during the war for lack of coal, there was considerable concern over their fuel supply especially after the flooding of the Kyushu mines. Conditions of their coal storage are reflected in Exhibit A, and it can be seen that the reserve storage reached a low of only slightly over one day's normal consumption.

3. The plant is owned by the Japan Electric Generation and Transmission Co. Information was obtained from M. Shintani, the superintendent who had been in charge only since April 1945 and was not too familiar with statistical details.

4. Normally, the plant uses 150 employees working in two shifts.

Attacks.

There was never any specific attack on the plant although there was slight damage indirectly attributable to attacks elsewhere. On 19 April 1945, during an attack on Kure, a surge caused destruction of 1 oil circuit breaker bushing. On 6 August 1945 the atomic bomb blast over Hiroshima destroyed 2 transformer bushings and damged slightly some sheet iron building walls. (Exhibit C, photo no. 1). The plant is 2 and 3/4 miles from the point of the atomic bomb explosion and was in operation at the time.

Effects of Bombing.

1. Physical Damage.

a. None directly and very minor damage indirectly.

2. Production Loss.

None

3. Recuperability Cycle.

Repairs were made immediately as spare bushings were on hand. Building damage required no repairs for plant operation.

4. Vulnerability.

Situated on the bay with no surrounding construction of importance, the plant could be easily detected in that it has no natural protection and offers all the weaknesses common to electric generating stations.

Intelligence Check.

1. *a.* OSS reports listed the plant correctly as to the location with good photographic coverage. However, the increase in capacity completed in 1941 was not included.

b. Air Objective Folder 90.30 correctly listed this plant and assigned target No. 796, although the 1941 extension was not mentioned.

2. This plant was never a primary target.

Data Relevant To Other Studies.

None

Evaluations and Impressions.

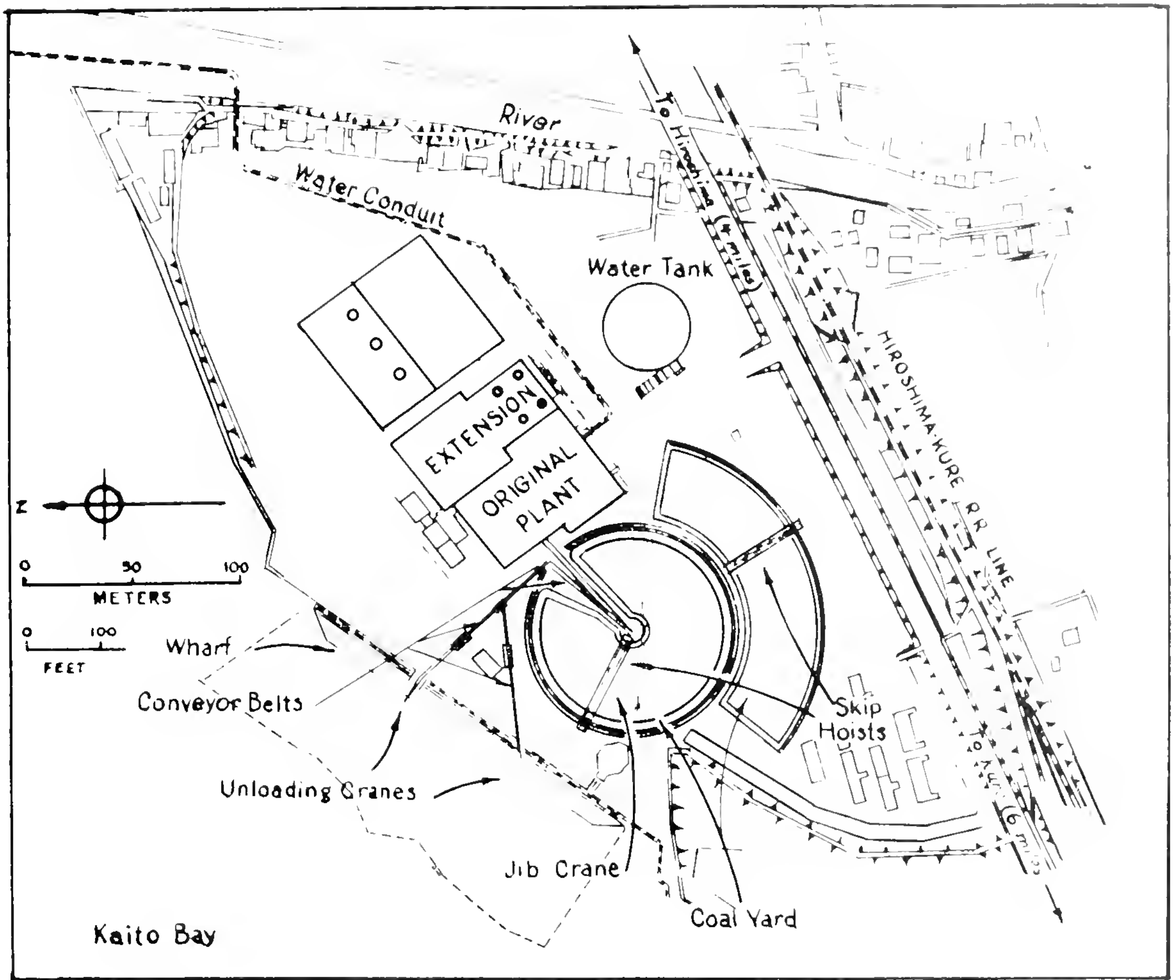
This plant was very important, and its importance was not evaluated in any intelligence reports. It could have been damaged very easily.

EXHIBIT A

Statistics on Plant Operation

	Generation KWH	Peak Load KW	Consumed Coal-Tons	Hours Operation	Coal in Stock End of Month
1942	172, 982, 732	52, 276 (Aug.)	146, 268	6, 838	16, 683 (Dec.)
1943	207, 169, 308	54, 930 (Aug.)	186, 119	7, 692	4, 551 (Dec.)
1944	185, 237, 422	55, 484 (Oct.)	186, 241	7, 685	1, 810 (Dec.)
Jan	25, 271, 092	46, 500	23, 647	733	7, 340
Feb	22, 271, 332	46, 500	19, 802	696	11, 401
Mar	11, 969, 096	41, 400	10, 248	621	11, 689
Apr	6, 279, 978	35, 900	5, 267	423	12, 178
May	17, 543, 346	45, 000	15, 938	673	4, 787
June	22, 870, 384	42, 496	22, 942	720	813
July	21, 268, 472	45, 086	22, 420	741	4, 609
Aug	15, 305, 436	39, 220	17, 006	735	2, 817
Sept	12, 819, 032	38, 900	15, 396	670	5, 546
Oct	6, 206, 454	55, 484	7, 867	519	11, 301
Nov	10, 371, 600	48, 060	11, 239	566	9, 938
Dec	13, 061, 200	43, 120	14, 470	583	1, 810
1945					
Jan	18, 360, 300	43, 000	18, 538	710	2, 269
Feb	15, 104, 800	38, 800	15, 878	672	1, 826
Mar	575, 800	11, 700	692	49	8, 580
Apr	320, 000	5, 000	490	93	8, 825
May	2, 001, 200	15, 000	2, 948	463	7, 562
June	3, 159, 000	24, 800	3, 433	382	8, 257
July	0	0	0	0	13, 641
Aug	980, 000	23, 300	1, 230	118	14, 297

Data taken from Japan Electric Generation and Transmission Co. monthly reports on steam plant operation.



PLOT PLAN

SAKA
STEAM ELECTRIC PLANT
HIROSHIMA-KEN

EXHIBIT B

EXHIBIT C

Photo 1—SAKA STEAM ELECTRIC STATION

End wall on NE end of section 2, station 1 (25,000 KW extension) showing blast from atomic bomb in Hiroshima, 2 and 3/4 miles away.

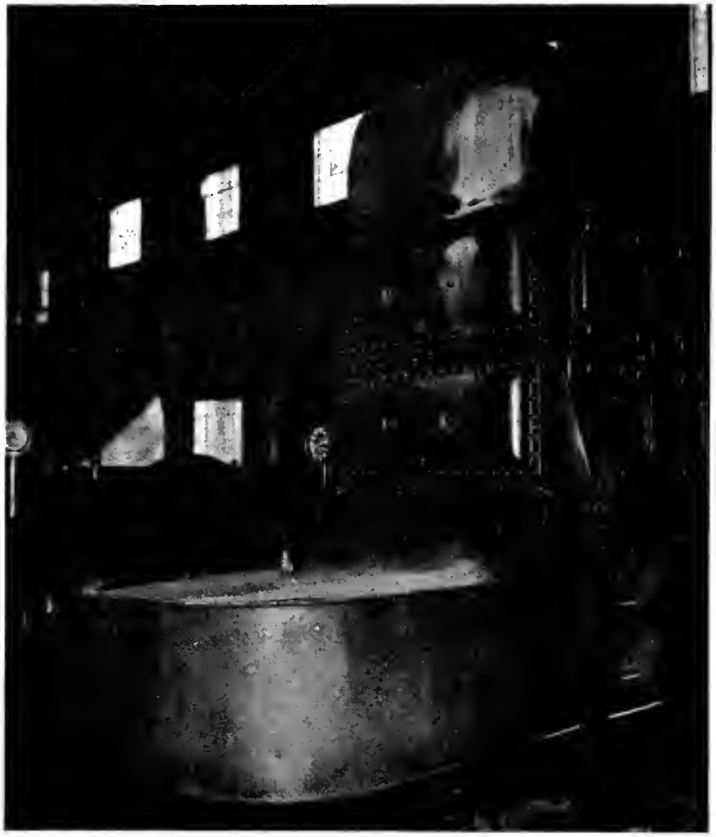


Photo 2—SAKA STEAM ELECTRIC STATION

7,000 KW Ljungstrum Turbogenerator

697713 -47 2

Photo 3—SAKA STEAM ELECTRIC STATION

Station No. 1, looking from south switchyard side, showing stacks of sections 1 and 2.

PLANT REPORT NUMBER 2

MEIKO STEAM POWER PLANT

NAGOYA, JAPAN

DATE INSPECTED 29 OCTOBER 1945

Summary.

1. The Meiko Steam Power Plant, located at the estuary of a branch canal of the Shonai River towards the Nagoya Harbor, has 159,000 KW installed generating capacity. It is in a large steel reinforced concrete building with coal storage and handling equipment on one side and outdoor transformer and switching station on the other. Its yearly output averaged approximately 276 million KWH during the 3 war years. It was the largest steam plant in the highly industrialized area of the Tokai (Nagoya) district and was very important especially during the dry season when hydro power was insufficient.

2. This plant was never a primary target but was damaged in three raids on adjacent targets by the Twentieth AF. On 17 May 1945, 3,598 tons of IBs were dropped in the entire raid of which a number of bombs (quantity unknown) fell within the effective area of this plant. On 26 June 1945, 346 tons of 2,000-lb. HE were dropped in the entire raid of which 22 bombs fell in this plant area. On 24 July 1945, 451 tons of 2,000-lb. HE bombs were dropped in the entire raid of which 4 bombs fell in this plant area.

3. All of the damage was very slight, and although the plant was not in operation at the time of the raids, the damage was insufficient to have caused any appreciable loss of production and was quickly repaired. However, the principal reason of slight damage and quick recuperation was because no bombs fell in any vital area, and the vulnerability of power plants existed since the entire plant would have been inoperative for a long period had any single vital place been hit.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been stated in the damage assessment report.

5. It is significant that during the raid of 17 May 1945 many incendiary bombs fell in the plant area which were extinguished without causing any damage. Power plants are constructed of noncombustible materials, and incendiary bombs have little or no effect.

The Plant and Its Function in Enemy Economy.

1. Product of plant and importance in enemy economy.

The Meiko steam electric generating plant is the most important generating plant in the Nagoya area and a very important plant in the power industry, ranking 4th in size in all Japan. It is primarily used as a base-load plant during the dry season, but it operates to some extent throughout the year supplementing the hydro plants and furnishing peak load requirements. The plant averaged 276 million KWH per year for the war years of 1942, 43 and 44, and the actual output from 1939 thru March 1945 is as follows:

	KWH
1939	168,965,160
1940	285,109,140
1941	166,579,560
1942	297,217,300
1943	286,079,100
1944	245,640,200
*1945	89,331,800

*Plant has not operated since March 1945.

The peak load during this period occured in January 1944 when a maximum generation of 150,900 KW was reached, and the plant operated 716 hours out of a possible 744 hours in this month.

The plant's output was supplied to the transmission lines of the Nippon Hassoden KK for general distribution, but the majority was utilized in the Nagoya area with some transmitted to Osaka and vicinity.

2. Physical description of plant.

a. The plant is located on Nagoya Bay on reclaimed land at the mouth of a canal of the Shonai River. The plant area is practically rectangular being approximately 1640 by 1200 ft with a total acreage of about 45 acres. (Exhibit A) The main plant (Exhibit B, photos 1 and 2) is in a steel and reinforced concrete building approximately 350 by 200 ft with a concrete roof. There are three stacks about 100 ft high made of heavy sheet iron. Both the building and stacks are camouflaged with black and white paint. On one side of the main building is located a coal handling storage area (Exhibit B, photo 2) covering about 16 acres. The rest of the area is occupied by an outdoor substation, many warehouses, and em-

ployees' residences. Adjacent to the power house is sufficient space reserved for an extension to double the present capacity. Two sides border along a canal with facilities for barge anchorage. The total name plate capacity is 159,000 KW in three main generators of 50,000-KW each and 9,000 KW in three house generators of 3,000-KW each. Two units, installed in 1939, are Mitsubishi make, and each has a house generator on the same shaft. The third unit is Hitachi and was installed in 1940. There is the separate 3,000 KW house turbogenerator. All units are impulse type with Curtis blading and utilize steam at approximately 600 lbs pressure at 720 degrees F. The boiler house contains 6 boilers each 150-t/hr based on coal of 11,500 Btu. Each boiler was designed to produce 25,000 KW and 2 boilers are connected in common feed to each turbine; however, the maximum obtainable power was never over 40,000 KW. Feed and make-up water is obtained from wells and city mains and cooling water from the bay.

b. The plant normally used coal from NE Japan shipped in by barge. During the war, water shipments became undependable, and much coal was received by rail especially Kyushu coal that was considerably poorer in quality. They did not have to shut down at any time during the war because of lack of fuel, despite the poor quality, since steam power plants received first priority on fuel supply.

3. The plant is owned by the Japan Generating and Transmission Co. Information was obtained from:

Mr. Shataro Yoneda	—Asst District Mgr Nippon Hassoden for Tokai District.
Mr. Shinoda	—Supt of Meiko plant.
Mr. Sumino	—Head of steam plant in district.
Mr. Seifi Takenchi	—District operating engineer for steam plants.
Mr. Shiro Sawa	—Chief Electric Engr for Meiko plant.

4. The plant normally uses approximately 230 employees, but during the war had cut down to 170. They operate two shifts. Although operation of the plant is normally seasonal, their employees are used continuously with nonoperating periods being devoted to maintenance.

Attacks.

There were no specific attacks on this plant; however, it received some slight damage during three raids directed against adjacent targets.

The first attack was 17 May 1945 during a night raid against southern Nagoya Urban Area, mission 176 of the Twentieth AF. In this raid 457 A/C of the 58th, 73rd, 313th, and 314th Wings dropped 3,598 tons of incendiary bombs from 8,000 to 16,000 ft with 3/10-9/10 weather. A number (quantity unknown) of IB bombs dropped within the plant compound but were extinguished before doing any damage.

The second damage occurred on 26 June 1945 during a daylight raid against Aichi Aircraft Works, Eitoku plant, mission 229 of the Twentieth AF. Fifty A/C of the 313th Wing dropped 346 tons of 2,000-lb GP bombs fused 1/100 sec nose no delay tail in 10/10 weather from a height of approximately 20,000 ft. In this raid, 22 bombs fell in this plant area of which none fell on buildings. Four workmen were killed and 2 injured.

The third damage was on 24 July 1945 during a daylight raid against Aichi Aircraft Works, Eitoku plant, mission 287 of the Twentieth AF. Sixty-six A/C of the 313th Wing dropped 451 tons of 2,000-lb GP bombs fused 1/100 sec delay nose no delay tail in 10/10 weather from a height of approximately 22,000 ft. Four bombs fell in this plant area of which none fell on the building. A dud was found (Exhibit B photo 4.) The bomb had the following marking:

GP	Lot. Eop-6-5	Eop-8-44
2000-lb	Explosive	2154 BLS
AN-M66	Bomb	33 Co Ft
TNT		
SHIA		

Effects of Bombing.

1. Physical damage.

a. (1). In the first raid, the plant sustained no damage. All bombs were IB types and were extinguished immediately.

(2). The damage on 26 June 1945 was as follows:

Four bombs destroyed two complete and one-half of two more operator houses. Four persons were killed and two injured.

Two near misses near substation damaged the cooling fins of the three 63,000-KVA, 3-phase transformers; heavy damage was done to the aluminum cell lightning arrestors and fragmentation broke many insulators. (Exhibit B, photos 3 and 5)

One bomb hit the grounding bed and also damaged cables between generators and transformer.

(3). The damage on 24 July 1945 was as follows:

One near miss close to substation did some additional damage to the lightning arrestors.

The protective measures in the outdoor substation consisted of blast barriers around the transformers made of timber walls with earth fill core about 15 ft

high and 4 to 5 ft wide on the bottom. (Exhibit B, photo 3) These blast walls were fairly effective and definitely saved one 63,000-KVA, 3-phase transformer from being damaged. There were blast barriers between the units in the generator hall that had been removed at the time of our inspection.

b. From information supplied by local officials and by personal inspection, a bomb plot has been prepared (Exhibit A).

2. Production loss.

a. No actual production loss occured. This plant had been out of operation since March 1945 as it was not needed. The load was rapidly declining due to industrial load losses, and sufficient hydro power was available to take care of the daily demand. The damage caused by the raids was only minor, and in every instance immediate repairs could have been made.

b. No substitution or modification necessary.

c. No loss of production from physical damage to plant. Some production loss due to poor grade of coal.

3. Recuperability cycle.

a. All damage caused by the raids was of minor nature, and in every instance repairs were made immediately.

b. No production had been reattained at the time of this inspection.

c. All of the plant could have been operated as only minor damage had occurred.

4. Vulnerability.

The vulnerability of all steam power plants is fully covered in the final report which is applicable to this plant.

Intelligence Check.

1. *a.* OSS report in general correctly identified this plant; however, the size and details were given incorrectly.

b. The Air Objective Folder No. 90.20 for Nagoya Area issued by the Office of the Assistant Chief of Air Staff, Intelligence, listed this plant as target No. 1598 and correctly located it on the map. However, the size of the plant both in KW and dimensions and number of stacks was given incorrectly.

c. JTG. information was correct, and aerial photographic coverage was excellent.

2. Records of the raids in which this plant was damaged is covered in reports in raids 176, 229 and 287 on targets 197 and 1729.

a. Damage Assessment Report No 77, covering raid of 17 May 1945 does not list any damage to this plant, and none occurred.

b. Damage Assessment Report No 124, covering raid of 26 June 1945 does not list any damage, and aerial photographs do not show this plant although there were 22 strikes in the plant area.

c. Damage Assessment Report No 177, covering raid of 24 July 1945 does not list any damage, and aerial photographs do not show this plant although there were four strikes in plant area.

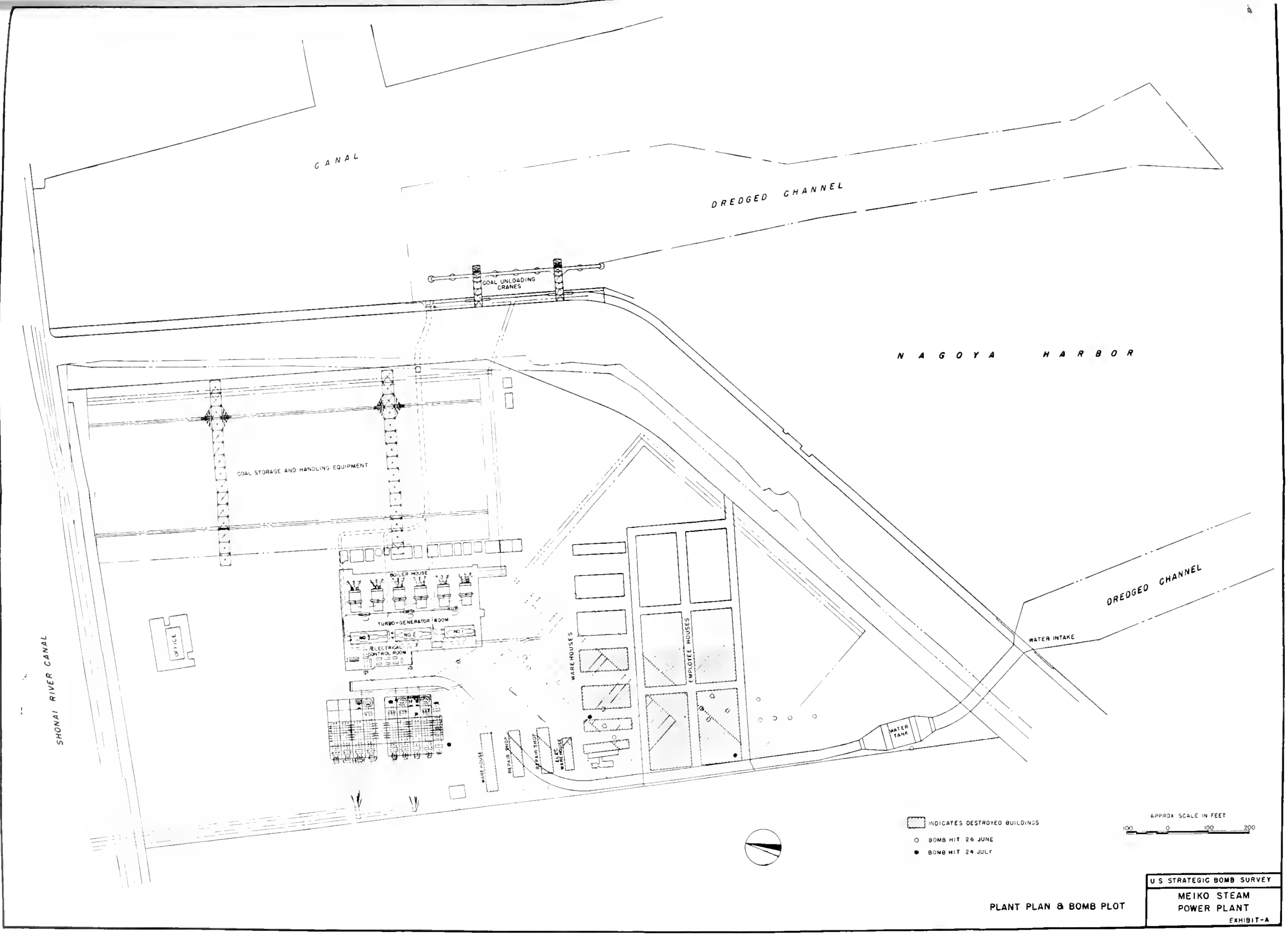
3. No mention was made in any damage assessments of recuperation or dispersal.

Data Relevant To Other Studies.

The shortage of coal and necessity of using poor grade coal was due to limited transportation facilities that became more difficult as the war went on, especially the curtailment of barge transportation of coal.

Evaluations and Impressions.

This plant is the latest addition to the Japan Generating and Transmission Co. It is considered the most efficient steam plant in Japan. The plant design is considered good, and maintenance was found fair. The entire plant is kept in readiness for immediate operation if necessary.



PLANT PLAN & BOMB PLOT

U S STRATEGIC BOMB SURVEY

MEIKO STEAM POWER PLANT

EXHIBIT-A

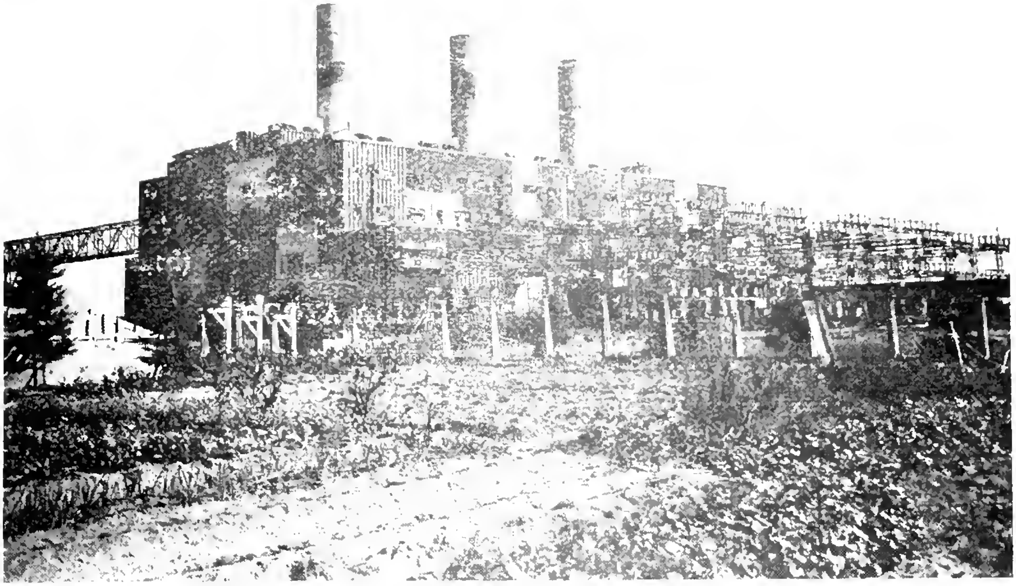


Photo 1—General view from northwest

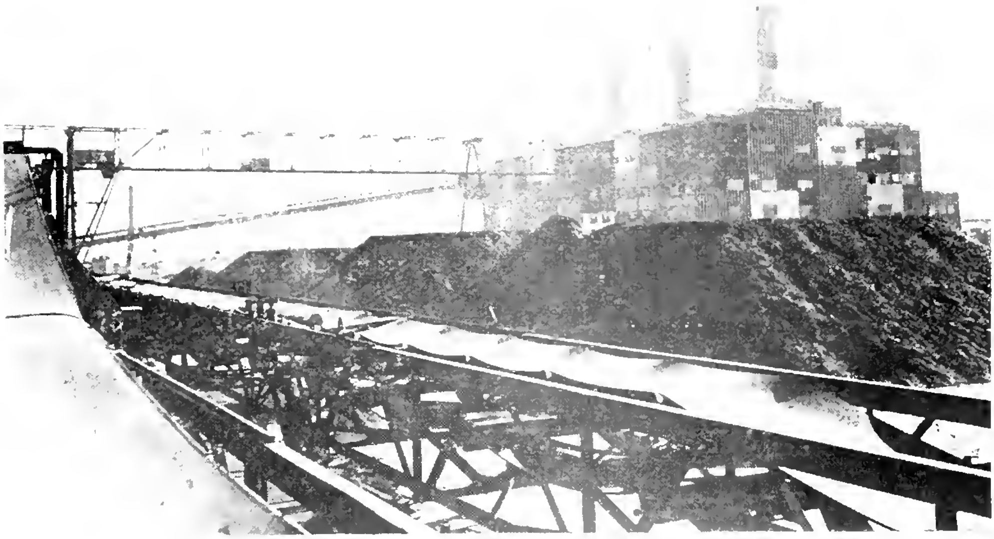


Photo 2—General view from northeast

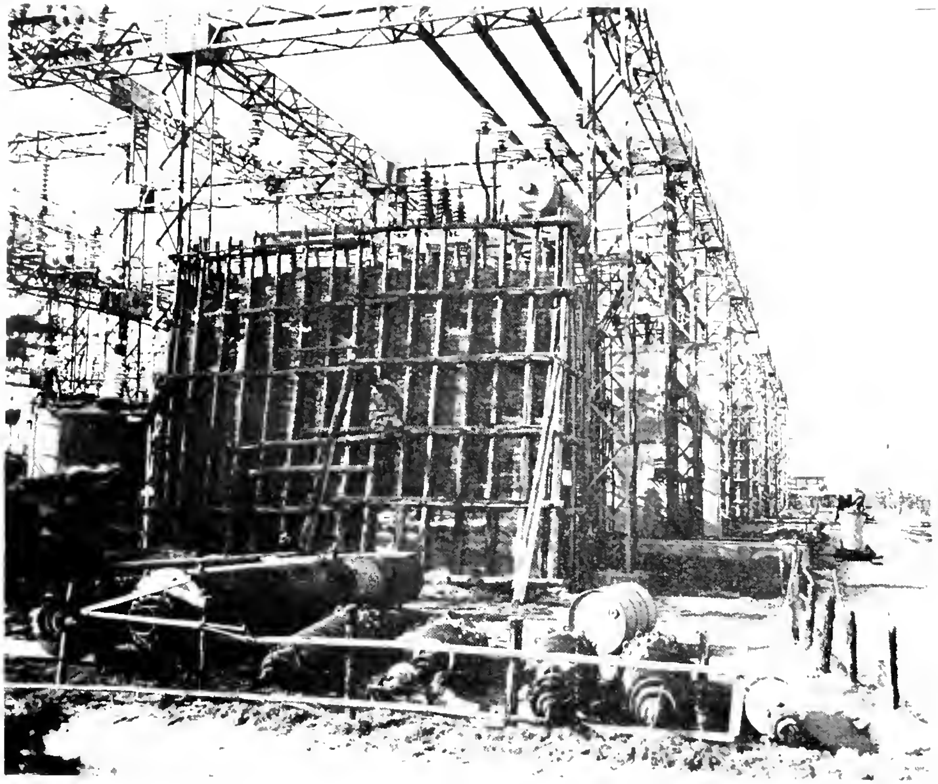


Photo 3—Damaged lightning arrestors and blast wall

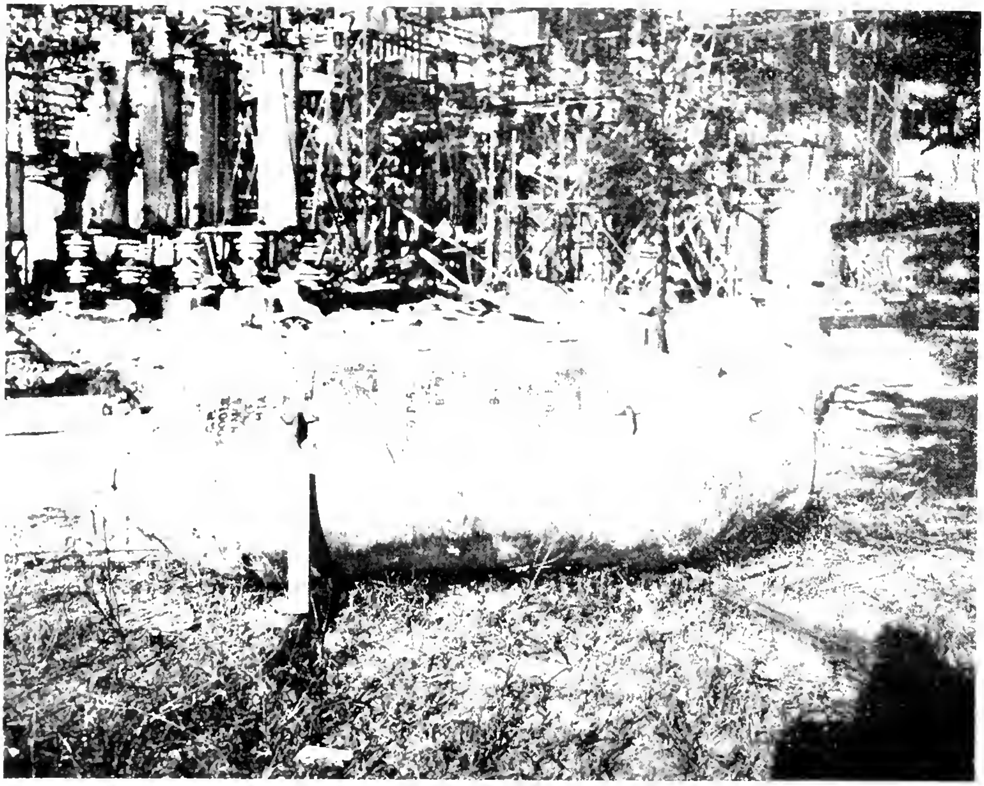


Photo 4—2,000 lb. unexploded bomb (12-inch stick on left)

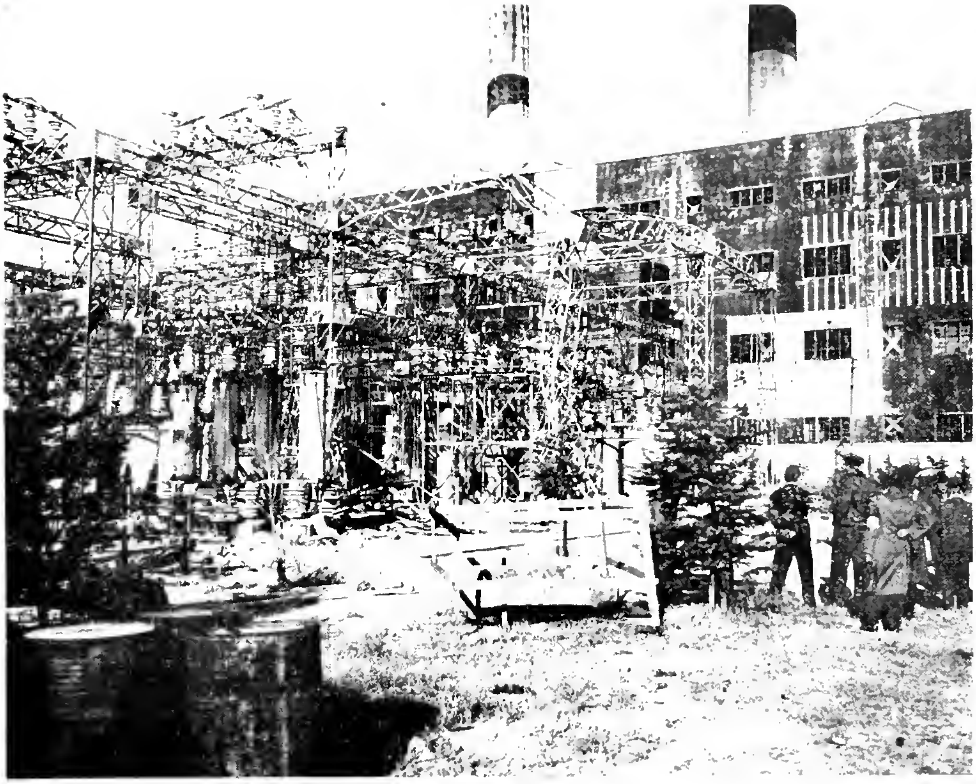


Photo 5—Damage to arrestors and substation

PLANT REPORT NUMBER 3

NAGOYA STEAM POWER PLANT

NAGOYA, JAPAN

DATE INSPECTED 30 OCTOBER 1945

Summary.

1. The Nagoya Steam Power Plant, located on an estuary of the Yamasaki River in Nagoya, has 144,000 KW in nominal (name plate) capacity. The main plant is in a large steel reinforced concrete building, with an indoor transformer and electrical bay and an outdoor switching station. A large coal storage and handling equipment installation is on one side. Its yearly output was approximately 85 million KWH during the three war years. It was an important plant in the highly industrialized area of Nagoya, being one of only two large steam plants there, and was especially important during the dry winter season when hydro power was scarce.

2. This plant was never a primary target, but was damaged in three raids on adjacent targets by the Twentieth AF. On 18 December 1944, 154 tons of IB and HE bombs were dropped in the entire raid. Nine HE and an unknown quantity of incendiary bombs fell in the effective area of the plant. On 11–12 March 1945, 1,790 tons of IB were dropped in the entire raid of which a number of bombs (quantity unknown) fell within the effective area of the plant. On 17 May 1945, 3,598 tons of IB bombs were dropped in the entire raid of which a number of bombs (quantity unknown) fell within the effective area of this plant.

3. Destruction of portions of the coal conveyor system, the coal bunker, the boiler operating controls and wiring, and minor buildings made up the principal damage. Also one main generator, one house generator, and other equipment was damaged. Due to previous severe earthquake damage, the plant was not in operation, but it was estimated that 35,000 KW in capacity was undamaged by bombing and could have been immediately utilized. Some minor recuperation had been started, and it is estimated that complete repairs could have been made in 3 months. The vulnerability of steam power plants is fully shown due to the large damage and production loss from a comparatively small number of bombs.

4. The size, importance, and location had been correctly evaluated in the intelligence data, but no damages had been reported in damage assessment reports.

5. This plant is a significant example of the ease with which steam power plants can be rendered inoperative and the small tonnage per acre required to do this.

The Plant and Its Function In Enemy Economy.

1. The Nagoya Steam Power Plant is the second most important steam plant in the Tokai district (Nagoya) and ranks 6th in all Japan. While it was principally used during the dry season, December thru February, it also supplemented hydro power at other times of the year. Its output was approximately as follows:

1942 81,000,000 KWH.
1943—115,797,000 KWH.
1944 68,000,000 KWH.
1945*—2,092,000 KWH.

*For Jan. and Feb. only—no appreciable production since then.

The energy was supplied to the transmission network for general distribution and was utilized principally in the Nagoya area, both for base and peak loads of particular importance during the dry season. It also supplied large quantities of energy at generator voltage of 11-KV, direct to the Mitsubishi Aircraft Works and Daido Iron Works located nearby.

2. *a.* The plant is located on the bank of the Yamasaki River at the juncture with Nagoya Bay. The plant area is triangular in shape with a total acreage of approximately 30 acres. (Exhibit A) The main building is of steel with reinforced concrete covering approximately 115,000 sq ft. It is built in an "L" shape with the generator hall and electrical bay in the long leg and the boiler house in the other. The original plant was built in 1925–26 with the size being doubled in 1934 to 1937. There is a total of 8 boilers, of which 4 were installed in 1925 each using 86-t/hr, 1 installed in 1934, and 3 in 1935 each using 90-t/hr. All boilers are B&W type CTM and are 350-lb psi at 400 degrees C. The 4 older boilers used 2 concrete stacks about 200 ft in height, and the 4 newer boilers each had an individual short steel stack. (Exhibit B, photo No 1.) There are 4 main turbogenerators of 35,000-KW each; 2 are GE make installed in 1926, 1 is an AEG installed in 1935, and 1 is a Mitsubishi

installed in 1937. In addition, there are 2 separate house turbogenerators, 1 GE of 1,000-KW and 1 AEG of 3,000-KW. Total name plate capacity is 144,000 KW. The plant is easily identifiable by its 2 tall stacks and its location directly next to the large Mitsubishi Aircraft Works (Target No 194) and across the river from Nagoya Harbor piers (Target No 251).

b. The plant was designed for coal of approximately 11,500 Btu that was received from Hokkaido and Kyushu by barge. During the war, due to non-dependability of water shipments, coal of poorer quality from Honshu was substituted. This poorer coal was only 9,500 to 10,000 Btu, and thus, generation was reduced, and the maximum peak was 90,700 KW. There were no actual shut downs from the lack of fuel as power stations were given first priority in obtaining their supply.

3. The plant is owned by the Japan Electric Generation and Transmission Co. Information was obtained from:

Mr. S. Saito—Nagoya District Mgr. of Tokai Branch Nippon Hassoden.

Mr. Yoneda—Assistant District Mgr.

Mr. S. Nakamura—Director of the plant.

4. The plant normally uses approximately 160 employees, which has been reduced to 122 at present. They operated two shifts and made no reduction in employees during the seasons.

Attacks.

There were no specific attacks on this plant; however, it received some damage during three raids directed against adjacent targets.

The first damage was on 18 December 1944 during a daylight attack against the Mitsubishi A/C Plant, Nagoya, mission 13 of the Twentieth AF. Sixty-three A/C of the 73rd Wing dropped 154 tons of HE and IB from 28,000 to 32,000 ft with 5/10 weather. In this raid 9 HE bombs fell in this plant area besides an unknown quantity of IBs.

The second attack was on 11–12 March 1945 during a night raid on the Nagoya Urban Area, mission 41 of the Twentieth AF. Two hundred and eighty-five A/C of the 73rd, 313th and 314th Bombardment Wings dropped 1,790 tons of IB bombs from 5,100 to 8,500 ft with 2/10 weather. In this raid a number (quantity unknown) of IB bombs dropped within the plant area but were extinguished before doing any damage.

The third attack was 17 May 1945 during a night raid on the southern Nagoya Urban Area, mission 176 of the Twentieth AF. Four hundred fifty-seven A/C of the 58th, 73rd, 313th and 314th Wings dropped 3,598 tons of IB from a height of 8,000 to 16,000 ft with 3/10–9/10 weather. In this raid a number of IB dropped within the plant area but were extinguished before doing any damage.

Effects of Bombing.

1. Physical damage.

a. (1) The damage on 18 December 1944 was as follows:

One bomb struck near the side of the generator hall doing slight building damage and damaging a nearby oil storage warehouse.

Two bombs hit the boiler house damaging one coal bunker and conveyor and boiler control wiring.

One bomb hit on the generator hall detonating near the roof and doing small damage to crane rail, one main generator, and one house generator.

One bomb struck and damaged part of the cooling water tunnel.

One bomb damaged a steel transmission tower.

Two bombs hit the coal storage area destroying part of the coal conveyor and controls.

One bomb struck in the center of employees houses destroying five houses.

Incendiary bombs burned two warehouses. 10 employees were killed in this raid.

(2) The damage on 11–12 March 1945 was the burning of two warehouses and several employees houses.

(3) The damage on 17 May 1945 was the destruction by fire of six employees houses, 1 warehouse, second floor of main office, part of the laboratory, and damage to coal-handling crane rails and controls.

Bomb protection barriers made of concrete were placed between the turbogenerators, and concrete pill-boxes for employees were placed throughout the plant.

b. From information supplied by local officials and by personal inspection, a bomb plot has been prepared. (Exhibit A).

2. Production loss.

a. No actual production loss occurred because of bombing since the plant was out of operation due to previous earthquake damage. However, the production loss, had the plant been in running condition at the time of bombing, would have been 75 percent of its average output for the period required for recuperation, or approximately 51 million KWH.

b. No substitution or modification was possible.

c. (1) Seventy-five per cent of the plant was rendered inoperative due to damage to coal conveyor system, boiler controls, and one generator unit.

(2) No production was lost thru diversion of labor, material, or machine facilities.

(3) No loss of production was caused thru protective measures.

(4) No loss was caused thru absenteeism or unusual inefficiency.

(5) A loss of production was caused throughout the war because of a poor grade of coal used due to lack of transportation for the better coal.

3. Recuperability cycle.

a. Based on the ability to secure materials and skilled labor, it is estimated repairs could be made within 90 days from the damage of 18 December 1944. No recuperability to damages from other raids is estimated as they were not vital to plant operation.

b. None of the lost production had been reattained at time of the inspection.

c. A portion of the plant could be utilized and has a capacity of 35,000 KW.

4. Vulnerability.

The vulnerability of all steam plants is fully covered in the final report which is applicable to this plant. In particular, the vulnerability of steam plants is shown here due to the stoppage of production thru relatively small damage.

Intelligence Check.

1. *a.* OSS. report in general correctly identified and evaluated this plant. However, the accompanying cuts and photograph show the original plant of 1926.

b. The Air Objective Folder No 90.20 for the Nagoya Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as target No 195 and correctly located it on the map.

c. JTG. information was correct, and aerial photographic coverage was excellent.

2. Records of the raids in which this plant was damaged are covered in the reports on raids 13, 41, and 176 on the target in the Nagoya Urban Area (194).

a. Damage Assessment Report No 1, covering raids of 17–18 Dec 1944, target 194, does not list any damages to the plant, although damage had occurred. Page 2 of JTG, sheet 90:20-195-T1, mentions that at least 2 hits were made on the plant in this raid, but did not estimate any damage.

b. Damage Assessment Report No 18, covering raids of 12 March 1945, target Nagoya area, does not list any damage to this plant.

c. Damage Assessment Report No 77, covering raids of 17–18 May 1945 does not list any damage to this plant.

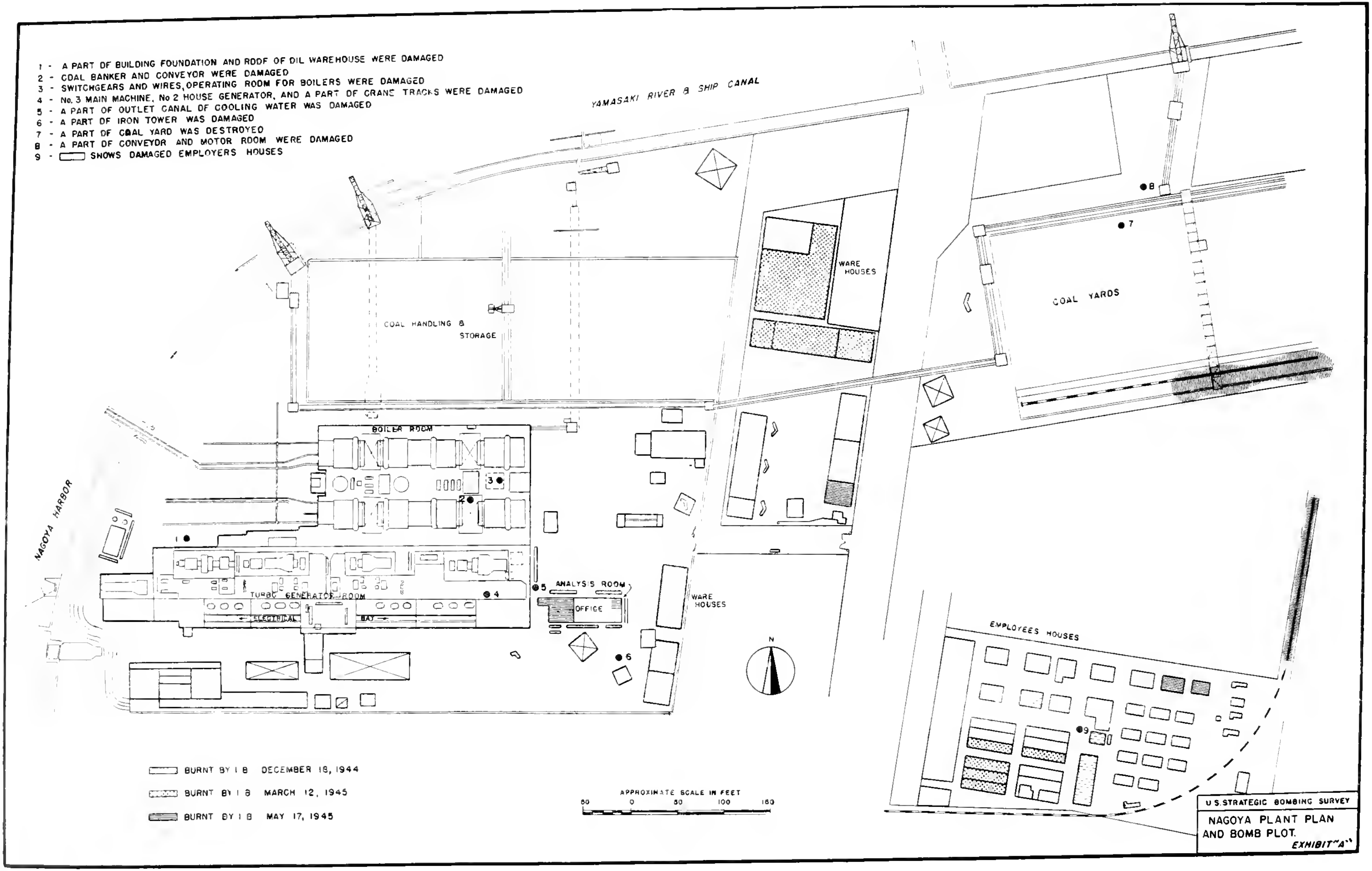
3. No mention was made in any damage assessment of recuperation or dispersal.

Data Relevant To Other Studies.

The shortage of coal and the necessity of using poor grade coal was due to limited transportation facilities that became more difficult as the war went on.

Evaluations and Impressions.

On 7 December 1944 an earthquake damaged the plant which made it completely inoperable and was more severe than the damage by the bombing. Most of the damage occurred in the boiler room, and repairs were not completed until February 1945.



NAGOYA PLANT PLAN AND BOMB PLOT.
EXHIBIT "A"

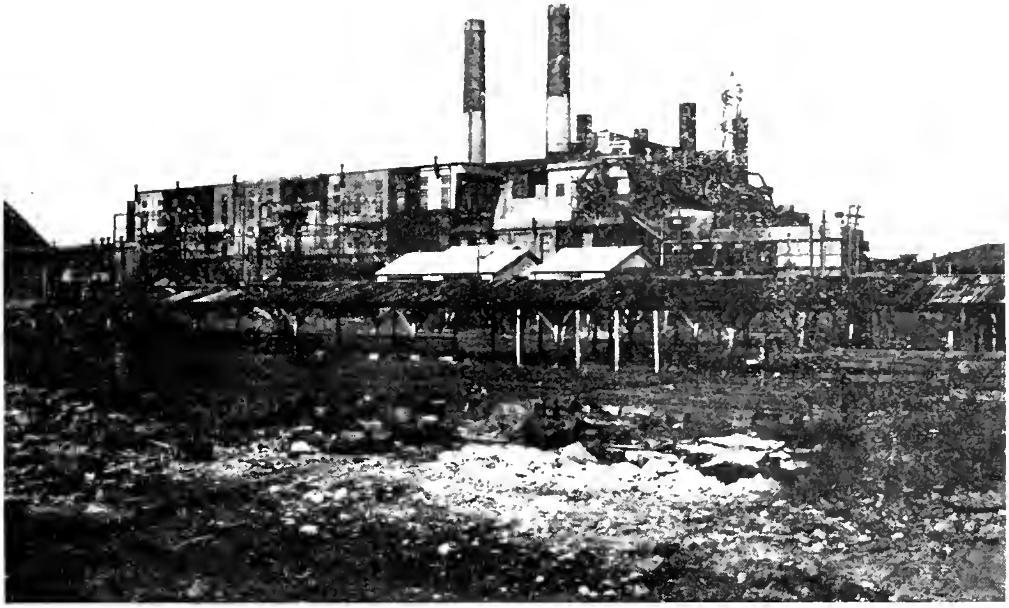


Photo 1—General view from southeast

PLANT REPORT NUMBER 4

AMAGASAKI STEAM POWER PLANT NO. 1

AMAGASAKI (NEAR OSAKA) JAPAN

DATE INSPECTED 30 OCTOBER 1945

Summary.

1. The Amagasaki Steam Power Plant No 1, located on the NE side of Amagasaki Harbor in Osaka Bay, has a name plate rating of 318,000 KW. It is in a 2 bay, large concrete building with coal storage and handling equipment on one side and outdoor transformer and switching station on the other. It is the largest steam plant in Japan and very important to the highly industrialized area of Osaka-Amagasaki-Kobe, especially during the dry season.

2. This plant was never a primary target but was damaged in a raid on the adjacent Nippon Oil Refinery by the Twentieth AF on 9–10 August 1945. A total of 914.3 tons of bombs were dropped on this raid, and plant personnel estimate between 500 and 600 bombs fell on Amagasaki No 1 and the adjacent Amagasaki No 2 plant.

3. The principal physical damage was complete destruction of sections of coal conveyors, moderate damage to 2 boilers and 1 stack, and damage to ½ of the main transformer banks and outdoor switching structure. One-half of the plant was rendered completely inoperable for a long period of time even had materials been available for repairs. The actual production loss can not be accurately estimated as the power demand was down at the time of the damage, but based on the average output of 448 million KWH per annum and a 50 percent plant loss for 1 year, at least 224 million KWH loss was caused. Practically no attempt at recuperation has been made. The vulnerability of power plants is clearly shown for destruction of certain parts renders complete units inoperative.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been reported in the damage assessment report.

5. This plant was one of the group composed of Amagasaki No 1, Amagasaki No 2, and Amagasaki East, all of which were located very close together. This combined group was by far the largest generator of electric energy in all Japan. Their output was approximately ½ billion KWH in 1943 or 4 percent of all generation and almost 10 percent of the total generation of thermal plants. This was a factor of prime importance to the highly industrialized area in which they were located and to the war industry as a whole. Target information issued by the Joint Target Group had correctly summarized this situation but had not fully exploited the real significance or ease with which these plants could have been destroyed. It is very apparent that a splendid opportunity existed here to apply a relatively small expenditure of strategic bombing and achieve a remarkably destructive result.

The Plant and Its Function In Enemy Economy.

1. Product of the plant and importance in enemy economy.

The Amagasaki No 1 was one of the most important in Japan as well as largest in size. While it was principally used during the dry season between November and March, it also supplemented hydro power at other times of the year. The annual generation in KWH was exceeded by only one other steam plant in Japan, namely the adjacent Amagasaki No 2 plant. Its annual output, maximum peak month and peak KW load, during the war years was as follows:

Year	Annual Output KWH	Peak Mo. KWH	Peak KW
1942	545,316,790	94,807,500 (Dec.)	209,200 (Jan.)
1943	521,937,600	98,119,800 (Jan.)	201,900 (Feb.)
1944	296,856,100	73,839,700 (Jan.)	165,200 (Jan.)
*1945	78,257,400	46,880,000 (Jan.)	139,500 (Jan.)

*Two months - only negligible operation since February 1945.

The output was supplied to the transmission network for general distribution with the majority utilized in the Osaka-Amagasaki-Kobe area, both for base and peak load.

2. Physical description of plant.

a. This plant, with the companion plant Amagasaki No 2, is located on the NE side of Amagasaki Harbor in Osaka Bay, occupying the major portion of an oblong 1600 by 3500 ft island of reclaimed land with Amagasaki No 1 on the North and Amagasaki No 2 on the South. This location is approximately midway between the outlets of the Muko and Kanzaki Rivers and approximately 1.75 miles WNW from the mouth of the Shinyodo River. The plant

area is nearly rectangular in shape, approximately 930 by 1030 ft with a total acreage of 22 acres. (Exhibit A—coal yard and plant buildings, and Exhibit B—outdoor switch and transformer yard.) The main plant is housed in a reinforced concrete and steel building approximately 720 ft by 195 ft with a new grinder building under construction at the western end. (Exhibit C, photos 1 and 2.) The building is box shape with a flat concrete roof and 6 steel stacks which are readily visible. On the north of the main building is a large coal storage and handling yard, and on the south is a large switch and transformer yard with a transmission line leaving towards the west. On the south side of the plant area is located Amagasaki Plant No 2, west of which, across a rather wide canal, is located the Nippon Oil Refinery and Tank Farm, and directly across the canal to the west and north is the Amagasaki Steel Works Ltd.

The boiler room contains 6 B&W boilers and 6 Mitsubishi boilers of 160-t hr rating with pulverized coal firing. The generator room contains 6, tandem, compound, turbogenerator units, each rated 50,000 KW and each with a direct, connected, house generator rated 3,000 KW making a total of 318,000 KW name plate capacity. Three of these units are Mitsubishi, 1 is Metropolitan Vickers, and 2 are Ishikawa-Jima manufactured. The plant is operated on a unit basis, two boilers per turbogenerator unit. Adjacent to the plant is a large switch and transformer yard stepping up to 77 KV, with six 77-KV outgoing overhead lines (3 lines per tower) and 3 incoming 77-KV underground lines from Amagasaki No 2. To supplement house generators, there are also installed three 5,000-KVA and one 9,000-KVA 3-phase transformers stepping down from 77 KV.

b. The plant uses coal from Kyushu and Hokkaido of approximately 11,520 Btu shipped by boat. There was no power shut down due to lack of coal.

3. The plant is owned and operated by the Japan Electric Generation and Transmission Co. Information was obtained from the following:

Mr. S. Kadono—Chief Engr Kinki Branch.

Mr. S. Kaku—Generating and Transformation Engr, Kinki Branch.

Mr. N. Tsuchiyama—Steam Power Engr, Kinki Branch.

4. For operation during the war, approximately 200 employees were used, but at present have been reduced to about 75 working in two shifts. Although operation of the plant is normally seasonal, the employees are used continuously and during non-operating periods perform plant maintenance.

Attacks.

First Raid.

On 15 June 1945 between 0900 and 1000 an undetermined number of fire bombs were dropped on the plant and burned one warehouse. No record of this raid is in the mission report file.

Second Raid.

This plant was damaged during a raid directed against the Nippon Oil Refinery and Tank Farm, Target 1203, Mission 322 of the Twentieth AF on 9/10 August 1945. One hundred and seven A/C of the 315th Wing dropped 911.3 tons of 500-lb. GP bombs, fused 1/10 second nose and 1/40 second tail from a height of 15,200 to 17,300 ft with 0/10—8/10 weather. In this raid the number of bombs dropped falling in the plant area cannot be accurately determined, but it was estimated by plant personnel that from 500 to 600 bombs fell in the Amagasaki No 1 and No 2 plant area. No bomb plot could be made because with this number of bombs dropped, hits were so close together that they could not be individually identified. On the main buildings there were 10 hits, and a large number were made in the switch and transformer yard.

Effects of Bombing.

1. Physical damage.

a. The damage was as follows:

One bomb hit north the coal conveyor, completely destroying a considerable section. (Exhibit C, photo 3)

One bomb entered through the skylight over the space between boilers No 1 and 2, denotating near the base of boiler No 1, causing distortion of lighter metal parts, housings of all heaters, super heaters, etc., as well as causing fragmentation damage all around, and blasting the covering of water wall piping, but did not damage the heavier parts of the boiler.

One bomb hit the light metal support of the skylight between boilers No 1 and 2, causing only minor damage. (Exhibit C, photo 4)

One bomb hit a stack serving boilers No 1 and No 2, detonating inside the stack. (Exhibit C, photo 4 and Exhibit C, photo 2)

Four bombs hit on the ceiling of the turbogenerator room, detonating just below the concrete ceiling. Turbines No 1 and 2 were damaged by fragmentation, and minor damage was done to roof and walls. (Exhibit C, photo 5)

Several hits close to the sides of the new grinder house, damaging the building slightly.

Several bomb hits on the switch and transformer

put out of commission a large section of the steel structure support, disconnecting switches, oil circuit breakers, transformers, and did other general fragmentation damage. Transformer oil fires were started which burned for two days, causing additional damage particularly to transformers and distortion to steel structure. The totally damaged and partially damaged sections are indicated on Exhibit B and Exhibit C, photos 7 to 12.

Several bombs had evidently hit the transmission line conductors between the switch and transformer yard take off and the first tower as well as between the first and second towers, as several of the lower conductors were broken.

Protective measures taken consisted of the placing a 6 to 7 ft high concrete blast wall in the space between the turbogenerators, extending about 3/4 of the width of the bay (Exhibit C, photo 6), and placing at various points throughout the plant and plant area concrete shelters of different sizes for the workmen.

b. According to plant personnel 500 to 600 bombs fell in the plant area and open spaces around the Amagasaki No 1 and No 2 plants. It was impossible to obtain a bomb plot, nor could an accurate bomb plot be made as exact points of the hits were obliterated. (Exhibit B of report on Amagasaki No 2)

2. Production loss.

a. This plant was in operation throughout the war years, although production declined considerably in the latter part of 1944, and there was negligible production after March 1945. This was due to loss of load demands because of destruction of industry thru bombing and or to the incompleted program of industry dispersion. Therefore, it is not possible to accurately estimate the actual loss. Based on the average production of 448 million KWH during the 3 war years and the fact that 1/2 of the plant was rendered inoperative by the bombing, the potential loss amounted to 224 million KWH.

b. No substitution or modification was possible.

c. (1) The loss of production was directly caused by bombing and in particular to the limiting factor of transformer capacity.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) No other loss due to shortage of essentials.

3. Recuperability cycle.

a. The only repairs that had been made were to one of the 5,000-KVA auxiliary transformers, which was found not damaged internally. In the case of other damaged transformers, complete inspection had not been made to see whether the core and coils had been damaged beyond repair. The damage to the roof, skylights, or window frames had not been repaired, and not even window panes had been replaced to protect equipment from the weather. It was estimated, if material were available, that the damaged portion of the plant could be put back into complete operation in one year.

b. No production had been reattained in the damaged portion at the time of inspection.

c. The damaged portion could carry a load of 150,000 KW.

4. Vulnerability.

The vulnerability of this power plant is clearly shown and is more fully covered in the industry final report applicable to all steam power plants.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder, 90.25 for Osaka Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant by target 540 A, correctly located it on maps, evaluated its importance, and gave a reasonably correct plot plan. Photographic information was practically correct, except that it did not show the partially completed grinder house.

c. JTG information was essentially correct. Aerial photographic cover was excellent and locations of buildings were correct in all except one minor point in not identifying the partially completed grinder house.

2. *a.* Record of the raid in which this plant was damaged is covered in the report of raid 322 on target 1203.

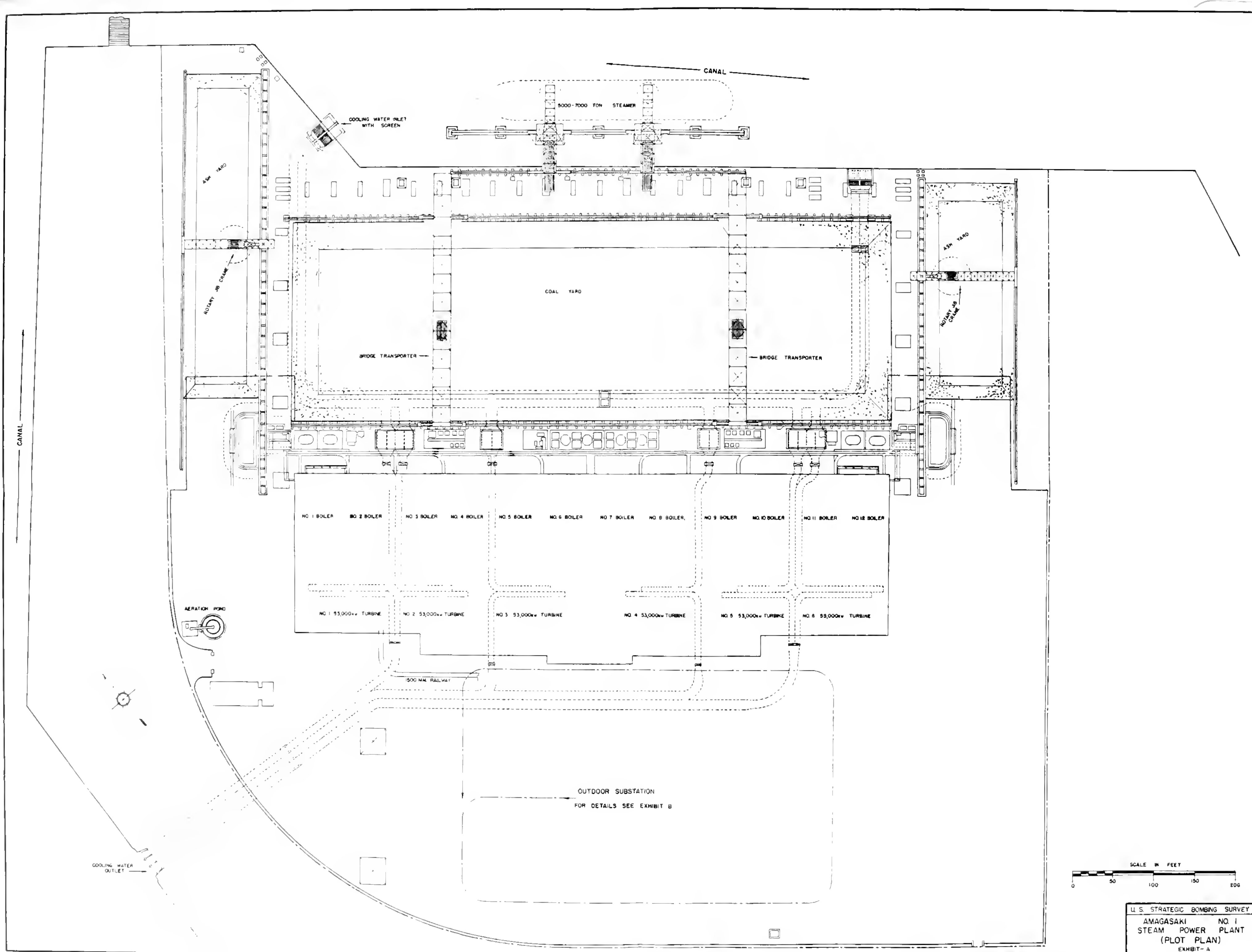
b. Strike Attack Report No 138 mentions the fact that, "possible misidentification of the peninsula to the right of the target as the target itself may have caused the tendency in general towards that side," but no estimate was made of the damage.

Data Relevant To Other Studies.

None

Evaluations and Impressions.

The importance of this plant, together with its two companion plants, Amagasaki No 2 and Amagasaki East, is most apparent. There was no other larger combine of steam power plants in Japan, and they were most important in the war economy.


CANAL
5000-7000 TON STEAMER
COOLING WATER INLET WITH SCREEN
ASH YARD
ROTARY JIB CRANE
COAL YARD
BRIDGE TRANSPORTER
BRIDGE TRANSPORTER
ASH YARD
ROTARY JIB CRANE
CANAL
NO. 1 BOILER
NO. 2 BOILER
NO. 3 BOILER
NO. 4 BOILER
NO. 5 BOILER
NO. 6 BOILER
NO. 7 BOILER
NO. 8 BOILER
NO. 9 BOILER
NO. 10 BOILER
NO. 11 BOILER
NO. 12 BOILER
NO. 1 53,000kw TURBINE
NO. 2 53,000kw TURBINE
NO. 3 53,000kw TURBINE
NO. 4 53,000kw TURBINE
NO. 5 53,000kw TURBINE
NO. 6 53,000kw TURBINE
AERATION POND
1500 MM. RAILWAY
OUTDOOR SUBSTATION
FOR DETAILS SEE EXHIBIT B
COOLING WATER OUTLET
SCALE IN FEET
0 50 100 150 200
U. S. STRATEGIC BOMBING SURVEY
AMAGASAKI NO. 1
STEAM POWER PLANT
(PLOT PLAN)
EXHIBIT - A

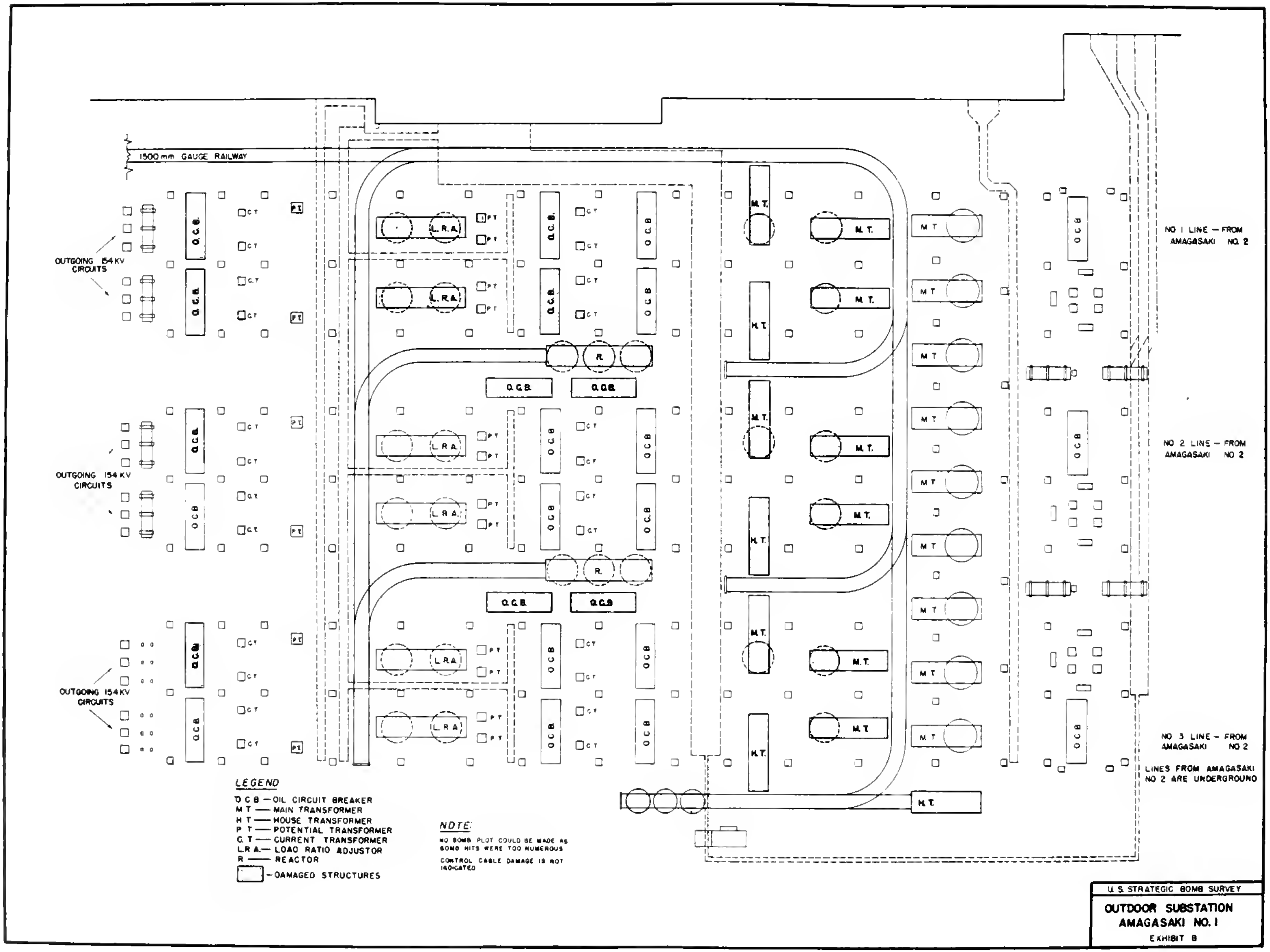

1500 mm GAUGE RAILWAY
OUTGOING 154 KV CIRCUITS
OUTGOING 154 KV CIRCUITS
OUTGOING 154 KV CIRCUITS
O.C.B.
P.T.
C.T.
L.R.A.
R.
M.T.
H.T.
NO 1 LINE — FROM AMAGASAKI NO 2
NO 2 LINE — FROM AMAGASAKI NO 2
NO 3 LINE — FROM AMAGASAKI NO 2
LINES FROM AMAGASAKI NO 2 ARE UNDERGROUND
LEGEND
O C B — OIL CIRCUIT BREAKER
M T — MAIN TRANSFORMER
H T — HOUSE TRANSFORMER
P T — POTENTIAL TRANSFORMER
C T — CURRENT TRANSFORMER
L.R.A. — LOAD RATIO ADJUSTOR
R — REACTOR
— DAMAGED STRUCTURES
NOTE:
NO BOMB PLOT COULD BE MADE AS BOMB HITS WERE TOO NUMEROUS
CONTROL CABLE DAMAGE IS NOT INDICATED
U.S. STRATEGIC BOMB SURVEY
OUTDOOR SUBSTATION AMAGASAKI NO. 1
EXHIBIT B

EXHIBIT C

Photo 1—General view looking south, with new grinder building, and transmission towers.

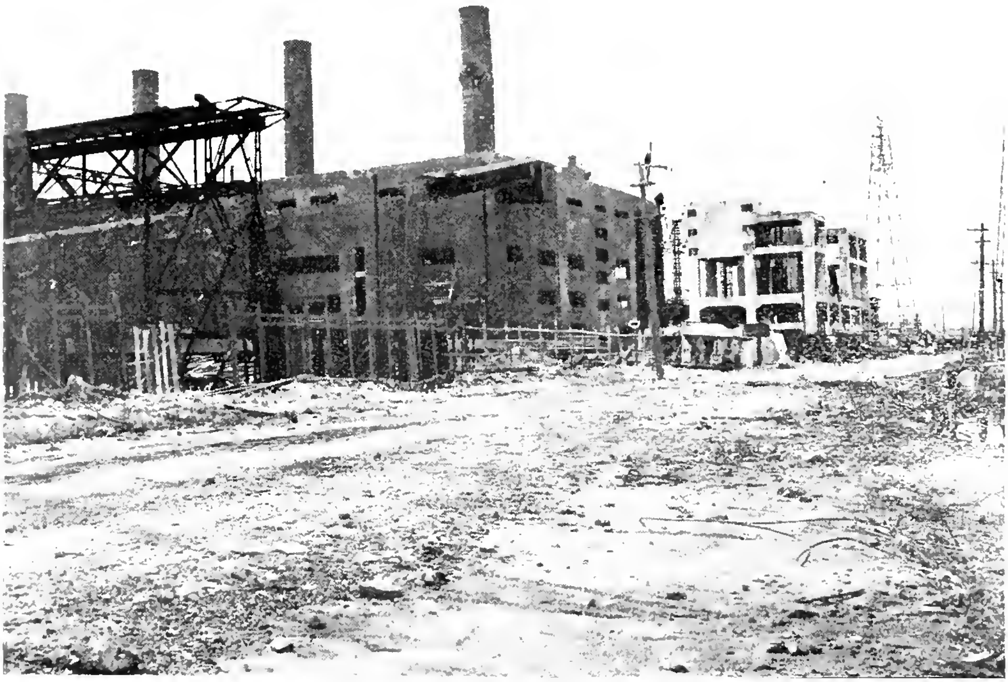


Photo 2—Closer view looking south showing west end, new grinder building and transmission towers.

Photo 3—Direct hit on north coal conveyors looking north.

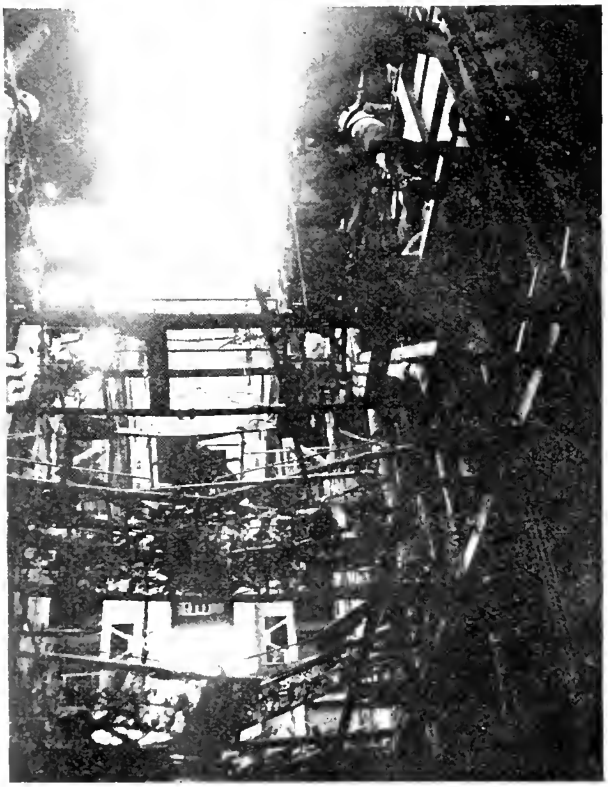


Photo 4—Looking up between boilers No. 1 and No. 2, showing damage to boilers, light iron, sky light support and bomb hit on stack No. 1.

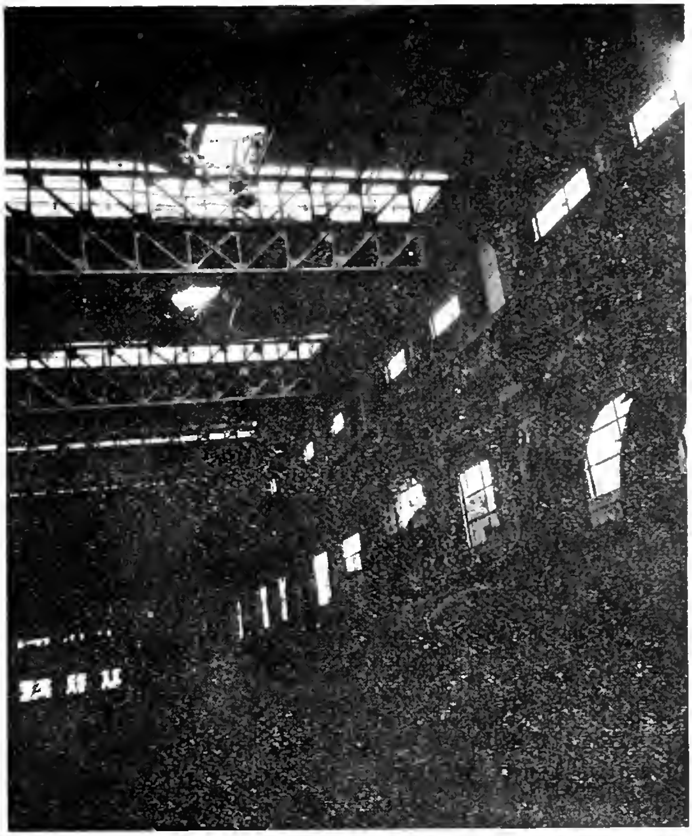


Photo 5—Two bomb hits on ceiling of turbogenerator room.

Photo 6—General view of switch and transformer yard.

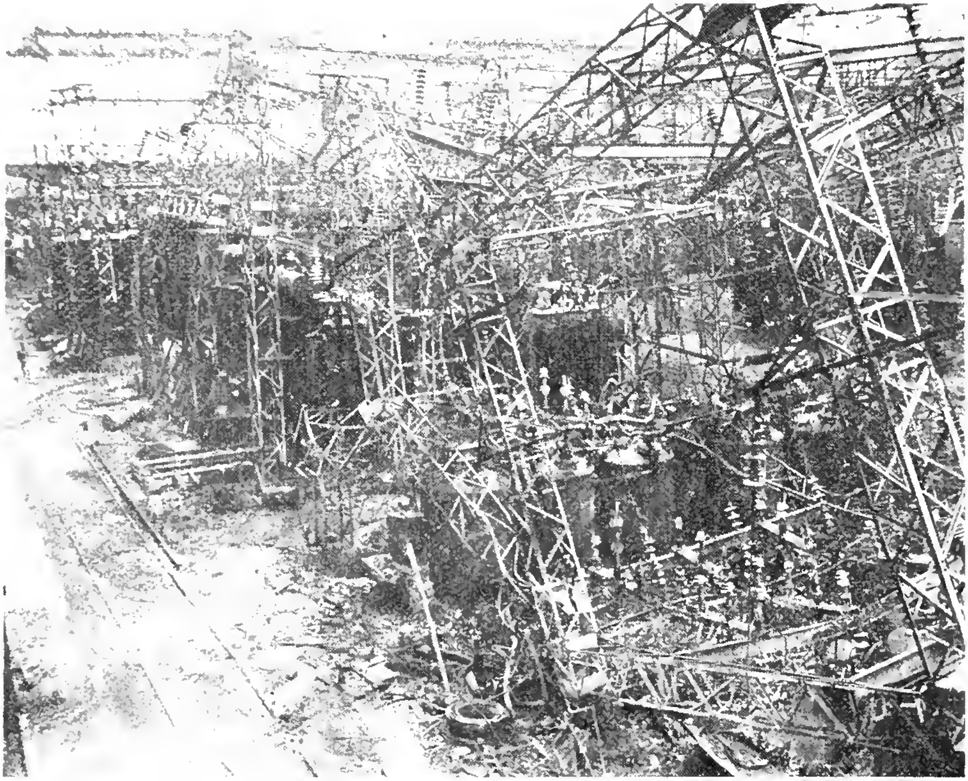


Photo 7—View of damaged switch and transformer yard

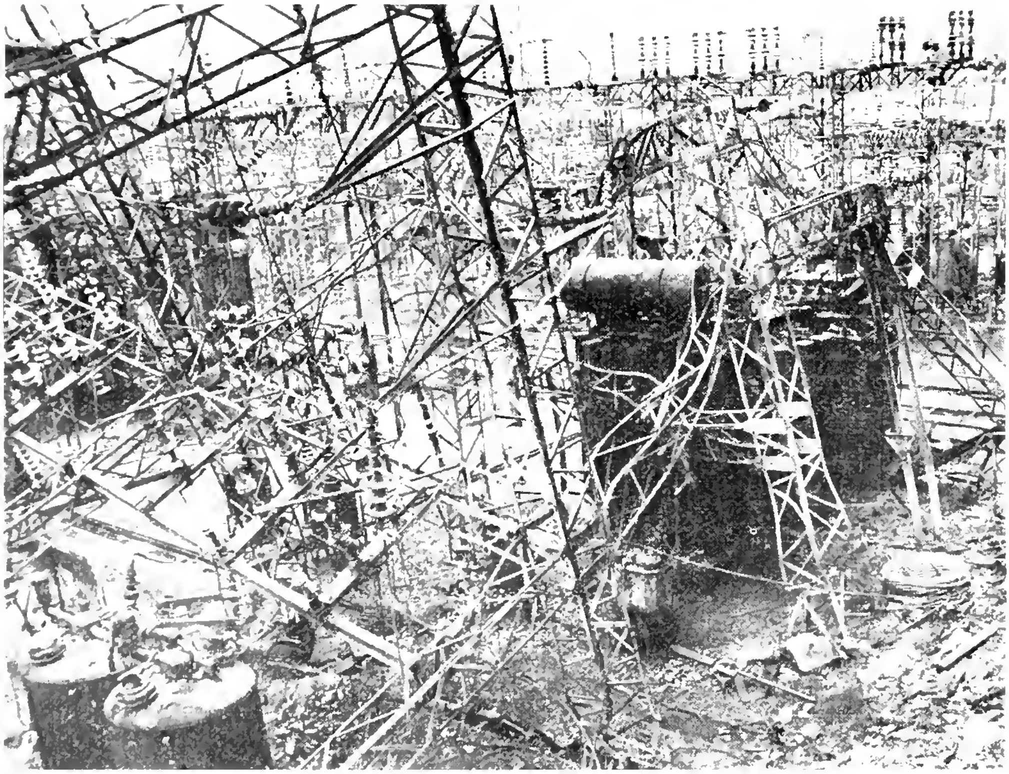


Photo 8—View of damaged switch and transformer yard

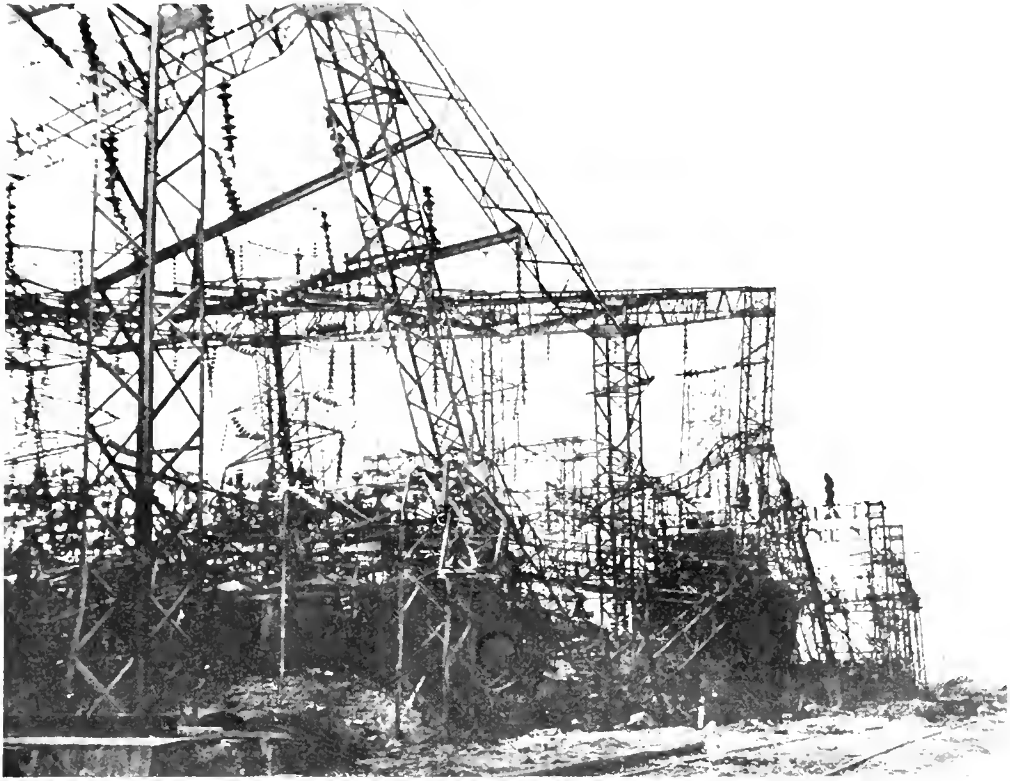


Photo 9—Ground view of damaged switch and transformer yard

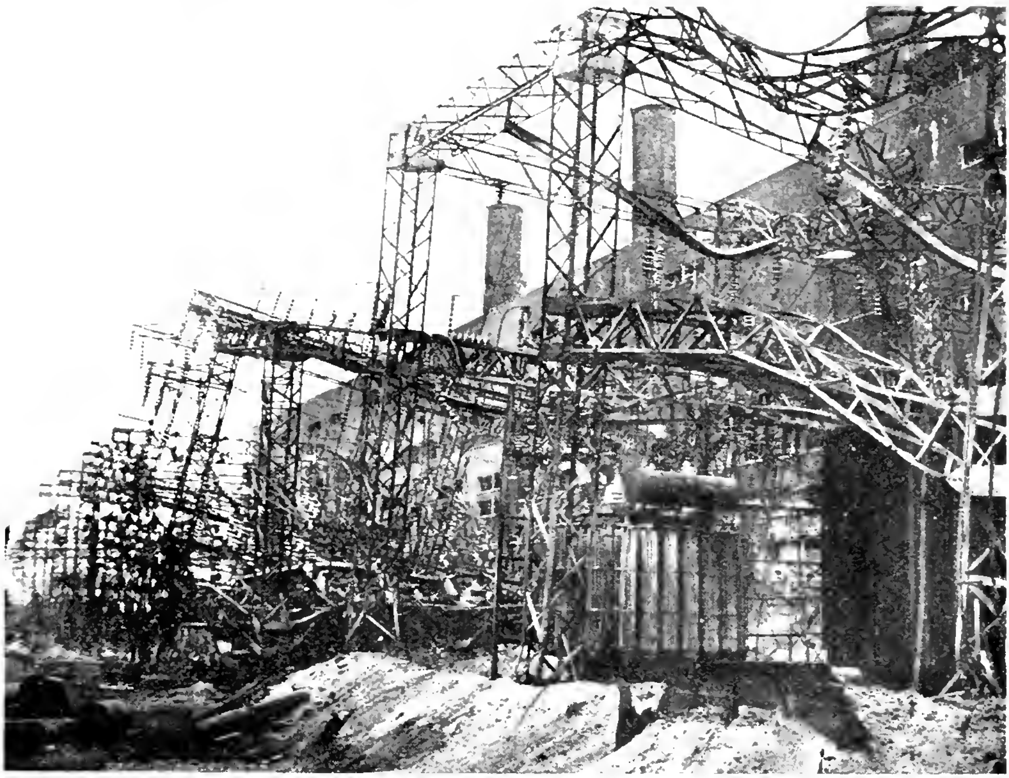


Photo 10—Ground view of damaged switch and transformer yard

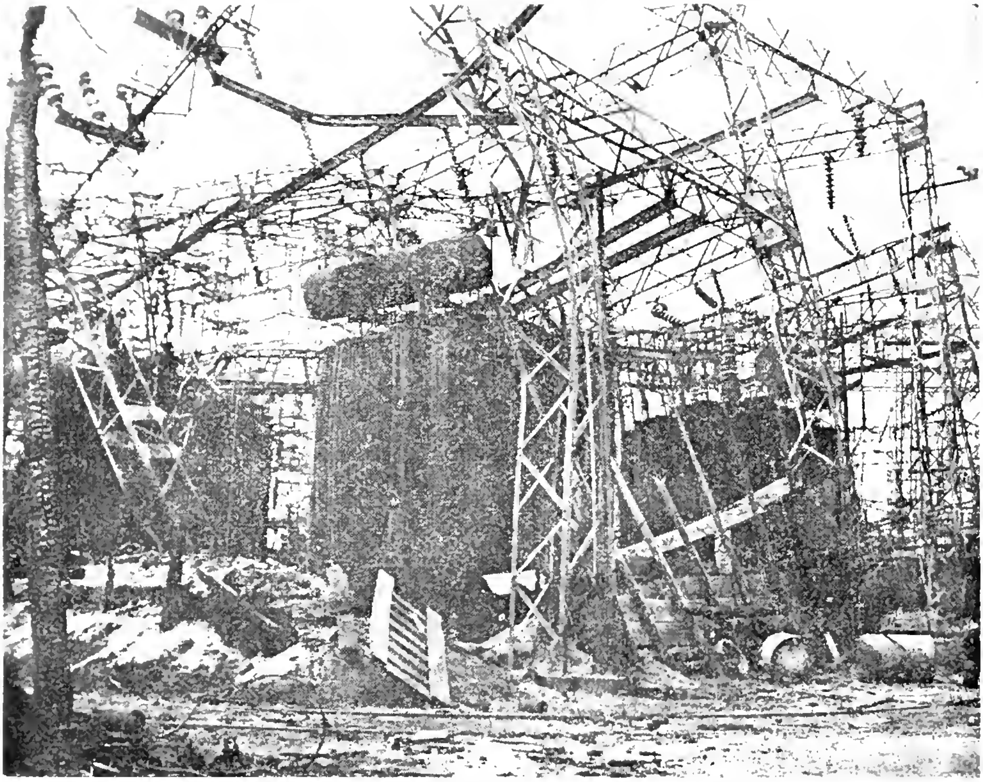


Photo 11—Closer view of damaged switch and transformer yard

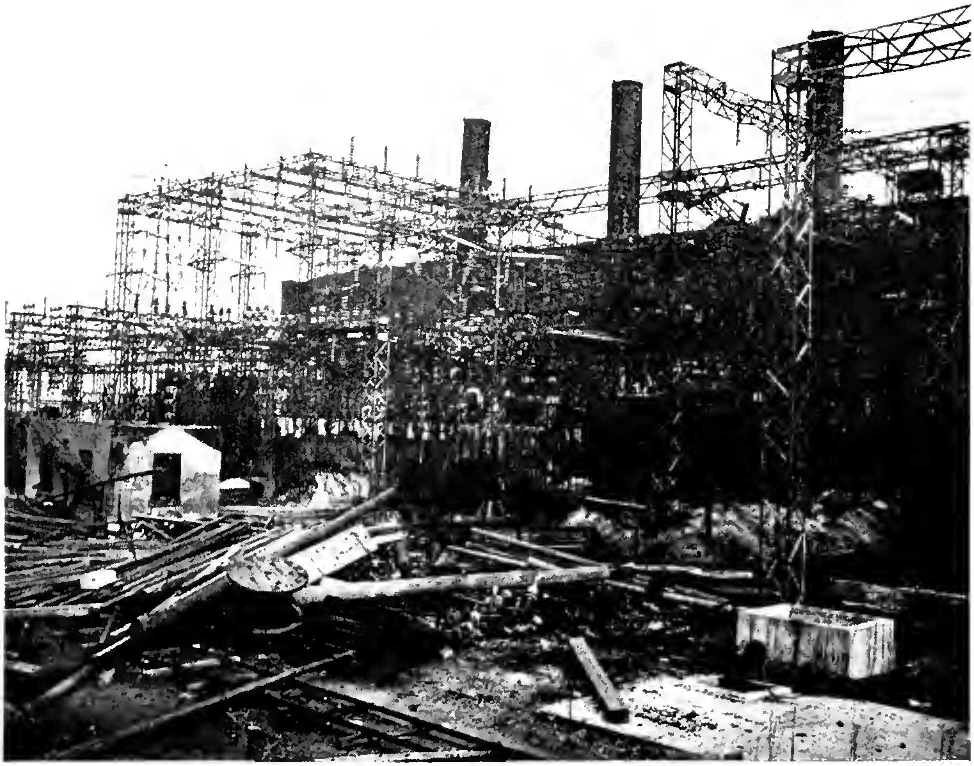


Photo 12—General view of part of switch and transformer yard showing some of damaged section

AMAGASAKI STEAM POWER PLANT NO. 2

AMAGASAKI (NEAR OSAKA) JAPAN

DATE INSPECTED 30 OCTOBER 1945

Summary.

1. The Amagasaki Steam Power Plant No 2, located on the NE side of Amagasaki Harbor in Osaka Bay, has a name plate rating of 300,000 KW. It is in a two bay, large, concrete building with coal storage and handling equipment on one side and indoor transformer and switching building on the other. It is the second largest in size and had the highest output of the steam plants in Japan. It was very important in the highly industrialized area of Osaka-Amagasaki-Kobe, especially during the dry season.

2. This plant was never a primary target, but was damaged in a raid on the adjacent Nippon oil refinery by the Twentieth AF on 9 10 August 1945. A total of 944.3 tons of bombs were dropped on this raid, and plant personnel estimated between 500 and 600 bombs fell on the Amagasaki No 2 and adjacent Amagasaki No 1 plants.

3. Physical damage was sustained throughout the entire plant. Principal damage was inflicted on coal handling equipment, boilers, turbines, generators, controls (both boiler and electrical) transformers, and switching equipment, any portion of which would have rendered the whole plant inoperable. The actual production loss cannot be accurately estimated as power demand was down at the time of the damage. However, the plant produced an average of 538 million KWH annually during the 3 war years, and based on estimated restoration of 50 percent of the plant capacity by the end of one year and complete capacity by the end of two years, the loss in production is approximately 807 million KWH. No attempt at recuperation had been made. The vulnerability of power plants is clearly shown, and the heavy damage with long period of recuperation clearly demonstrates the susceptibility of steam power plants to bombing.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been reported in the damage assessment report.

5. This plant was one of the group composed of Amagasaki No 1, Amagasaki No 2, and Amagasaki East, all of which were located very close together. This combined group was by far the largest generator of electric energy in all Japan. Their output was approximately 1½ billion KWH in 1943 or 4 percent of all generation and almost 40 percent of the total generation of thermal plants. This was a factor of prime importance to the highly industrialized area in which they were located and to the war industry as a whole. Target information issued by the Joint Target Group had correctly summarized this situation, but had not fully exploited the real significance or ease with which these plants could have been destroyed. It is very apparent that a splendid opportunity existed here to apply a relatively small expenditure of strategic bombing and achieve a remarkably destructive result.

The Plant and Its Function In Enemy Economy.

1. The Amagasaki No 2 was ranked second in importance in Japan as well as in size. While it was principally used during the dry season between November and March, it also supplemented hydro power at other times of the year. This plant generated more KWH annually than any other steam plant in Japan and, of all plants of any type, was exceeded in production only by one hydro plant. Its annual output, maximum peak month and peak KW load, during the war years was as follows:

Year	Annual Output KWH	Peak Month KWH	Peak Load KW
1942	753, 705, 000	117, 477, 000 (Dec.)	266, 000 (Dec.)
1943	660, 168, 000	116, 778, 000 (Feb.)	273, 000 (Feb.)
1944	410, 709, 000	95, 186, 000 (Feb.)	191, 000 (Feb.)
*1945	140, 937, 000	74, 557, 000 (Jan.)	183, 000 (Jan.

*Two months—only negligible operation since February 1945.

The output was supplied to the transmission network for general distribution with the majority utilized in the Osaka-Amagasaki-Kobe area, both for base and peak load.

2. *a.* This plant, with the companion plant Amagasaki No. 1, is located on the NE side of Amagasaki Harbor in Osaka Bay, occupying the major portion of an oblong 1600 by 3500 ft island of reclaimed land with Amagasaki No 2 on the south and Amagasaki No 1 on the north. This location is approximately midway between the outlets of the Muko and Kanzaki Rivers and approximately 1.75 miles WNW from the mouth of the Shinyodo River. The plant

area is nearly rectangular in shape approximately 965 ft by 1625 ft with a total acreage of 36 acres. (Exhibit A) The main plant is housed in a reinforced concrete and steel building approximately 625 ft by 225 ft. (Exhibit C, photo 1) The building is box shape with a flat concrete roof, and 5 steel stacks which are readily visable. Adjacent to and between the main building and canal is a large coal storage and handling yard. On the opposite side of the main building and separated by a 45 ft wide open space is a large switching and transformer house approximately 505 ft long (parallel to the main plant) by 118 ft wide of light steel construction with mostly glass or light material sides and end, and with hip-shaped lightweight roof. There are two transmission lines on single towers leaving the south end, paralleling the building, and then turning due north. To the north is located the Amagasaki Plant No 1, and on the west, across a rather wide canal, is located the Nippon Oil Refinery and Tank Farm, and directly across the canal to the west and north is the Amagasaki Steel Works.

The boiler room contains 2 Tokyo B&W boilers and 7 Mitsubishi boilers each of 220 t/hr rating with pulverized coal firing. The generator room has 4 tandem, compound, turbogenerator units, each generator 75,000 KW, totaling 300,000 KW in main generators. Two of these units are of Mitsubishi and two of Ishikawatima manufacture. The plant is operated on a unit basis with two boilers per turbogenerator unit and a provision to cut in a spare boiler. There are located in the switching and transformer house four 93,750-KVA banks of single-phase, OIWC transformers, stepping the generator voltage of 11 KV up to 77 KV, and five 8,000-KVA, 3-phase, OISC, house fransformers. In addition to the two 77-KV, outgoing, overhead lines (2 lines per tower), there are 3 outgoing, 77-KV, underground lines to Amagasaki No 1.

b. The plant uses coal from Kyushu and Hokkaido ot approximately 11,520 Btu brought by boat. There were no plant shut downs due to the lack of coal.

3. The plant is owned and operated by the Japan Generating and Transmission Co. Information was obtained from the following:

Mr. S. Kadono—Chief Engr, Kinki Branch.

Mr. S. Kaku—Generating and Transformation Engr, Kinki Branch.

Mr. N. Tsuchiyama—Steam Power Engr, Kinki Branch.

4. For operation during the war, approximately 200 employees were used who worked in 2 shifts. Although operation of the plant is normally seasonal, the employees were used continuously and during the nonoperating period performed plant maintenance.

Attacks.

First Raid.

On 15 June 1945 between 0900 and 1000 an undetermined number of fire bombs were dropped on the plant which burned down a warehouse and killed 2 men. No record of this raid is in the mission report file.

Second Raid.

On 19 July 1945 at 2000 to 2010 this plant was hit in a raid directed against the Nippon Oil Refinery and tank farm, target 1203, mission 281 of the Twentieth AF. Eighty-four A/C of the 315th Wing dropped 701.8 tons of 500-lb GP bombs fused 1/10 second nose, 1/40 second tail from a height of approximately 16,000 ft with 8/10—10/10 weather. In this raid one bomb hit the dock but caused no damage to the plant. In the strike attack report No. 126 no assessment of damage to this plant was made.

Third Raid.

This plant was completely put out of operation during a raid directed against the Nippon Oil Refinery and Tank Farm, target 1203, mission 322 of the Twentieth AF on 9/10 August 1945. One hundred and seven A/C of the 315th Wing dropped 944.3 tons of 500-lb GP bombs fused 1/10 second nose and 1/40 tail from a height of 15,200 to 17,300 ft with 0/10—8/10 weather. In this raid the number of bombs dropped that fell in the plant area cannot be accurately determined, but an estimate given by plant personnel was that between 500 to 600 bombs fell in the Amagasaki No 1 and No 2 plant area.

Effects of Bombing.

1. Physical damage.

a. (1) The raid of 15 June 1945 destroyed a wooden warehouse by fire with small loss of supplies. Bombs were incendiary and had no effect on the noncombustable plant structure.

(2) The raid of 19 July 1945 caused only slight damage to a dock on the canal and did no actual damage to the plant proper.

(3) The raid of 9/10 August 1945 was as follows: An undetermined number of bombs struck the boiler house doing serious damage to all boilers and damaging fans, piping, air heaters, economizers, super heaters, coal conveyors, one stack, supports, all instruments, and control. Exhibit C, photo 5 shows a general view of the roof of the boiler house and photo 6 shows damaged control board for boilers No 5 and 6 behind which can be seen the general

boiler, piping, and other damage. This is typical of the condition throughout the entire boiler house.

A number of bombs struck the turbogenerator room damaging the building and doing fragmentation and blast damage to the turbogenerators. Exhibit C, photo 8 shows damaged unit No 3. Other units also suffered damage.

Bomb hits on the south gantry crane, coal conveyors, and other parts put the entire coal handling equipment out of commission. Exhibit C, photos 4 and 7 shows portions of this.

One bomb made a direct hit on the main electrical control room destroying control panels and setting it on fire which in turn destroyed the control desk. Two operators who were in a bomb shelter in this room suffered no injuries. (Exhibit C, photo 9)

A large number of bombs struck the switching and transformer house. All transformers, and most of the oil circuit breakers, disconnecting switches, bus supports, coolers, pumps, control panels, and control cables were destroyed or very severly damaged directly or by the resulting fire. Exhibit C, photo 10 shows a general view of the switching and transformer house. Photo 11 shows a direct hit on an oil circuit breaker with fragmentation damage to others. Photo 12 shows where a bomb detonated near the base of a transformer bank destroying the center transformer and severly damaging an adjacent one on the left. Photo 13 shows the 3 oil coolers for one bank of transformers that has been damaged mostly by fire. In Exhibit C, photo 1 can be seen the damaged tower where transmission lines leave the plant. This photo, as well as Photos No 2 and 3, shows the wide spread destruction that existed throughout the plant.

Protective measures consisted of the placing of 6 to 7 ft high concrete blast-wall in the space between turbogenerators extending about $\frac{3}{4}$ of the width of the bay (Exhibit C, photo 8), and placing at various points throughout the plant and plant area concrete shelters of various sizes.

b. According to plant personnel interviewed, between 500 and 600 bombs fell in the area of this plant and the adjacent Amagasaki No 1. No bomb plot was available nor could an accurate one be made for with this number of bomb strikes, there were hits so close together that they could not be plotted individually. Exhibit B is an aerial photograph taken on 13 August 1945 and was a part of the damage assessment report No 191 on target 90.25–1203, Nippon Oil Refinery and Tank Farm. This photograph shows the large number of bombs dropped on this plant area. A line is drawn showing the approximate eastern limit of the bombed area.

2. Production loss.

a. This plant was in operation throughout the war although production declined considerably in the latter part of 1944, and there was negligible production after March 1945. This was due to the loss of load demands because of the destruction of industry thru bombing and or to the incompleted program of industry dispersion. Therefore it is not possible to accurately estimate the actual loss. Based on the average annual production of 538 million KWH during each of the 3 war years, and on the fact that the damage sustained would have caused a complete shut down for at least one year with restoration of only 50 percent capacity and another year for complete restoration, the loss in production caused is equivalent to approximately 807 million KWH.

b. No substitution or modification was possible.

(1) Plant was completely put out of commission by bombing.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) The only possible loss of production throughout the war would have been the fact that boiler tube replacements were hard to obtain.

3. Recuperability cycle.

a. At the time of inspection, no repairs had been made or even started, and there was not even any effort to protect any equipment from the weather. There is visable evidence of serious damage to some generator windings and to core and coils of transformers indicating necessity of complete replacements, but cases of fragmentation damage had not been examined to determine the extent of internal damage. It is conservatively estimated that, under favorable conditions of material and labor supply, it would require at least one year to place one-half of the plant back in operation and another year before the entire plant could be completed.

b. No production had been reattained at the time of inspection.

c. No portion of the plant could have been utilized due to destruction or damage to so many portions essential to the entire plant.

4. Vulnerability.

The vulnerability of all steam power plants is fully covered in the final report which is applicable to this

plant. However, this is a good example of the completeness of destruction that can be done.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder 90.25 for Osaka Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant by Target 540 B, correctly located it on maps, evaluated its importance, and gave a reasonably correct plot plan. Photographic information was lacking.

c. JTG information was essentially correct. Aerial photographic cover was excellent.

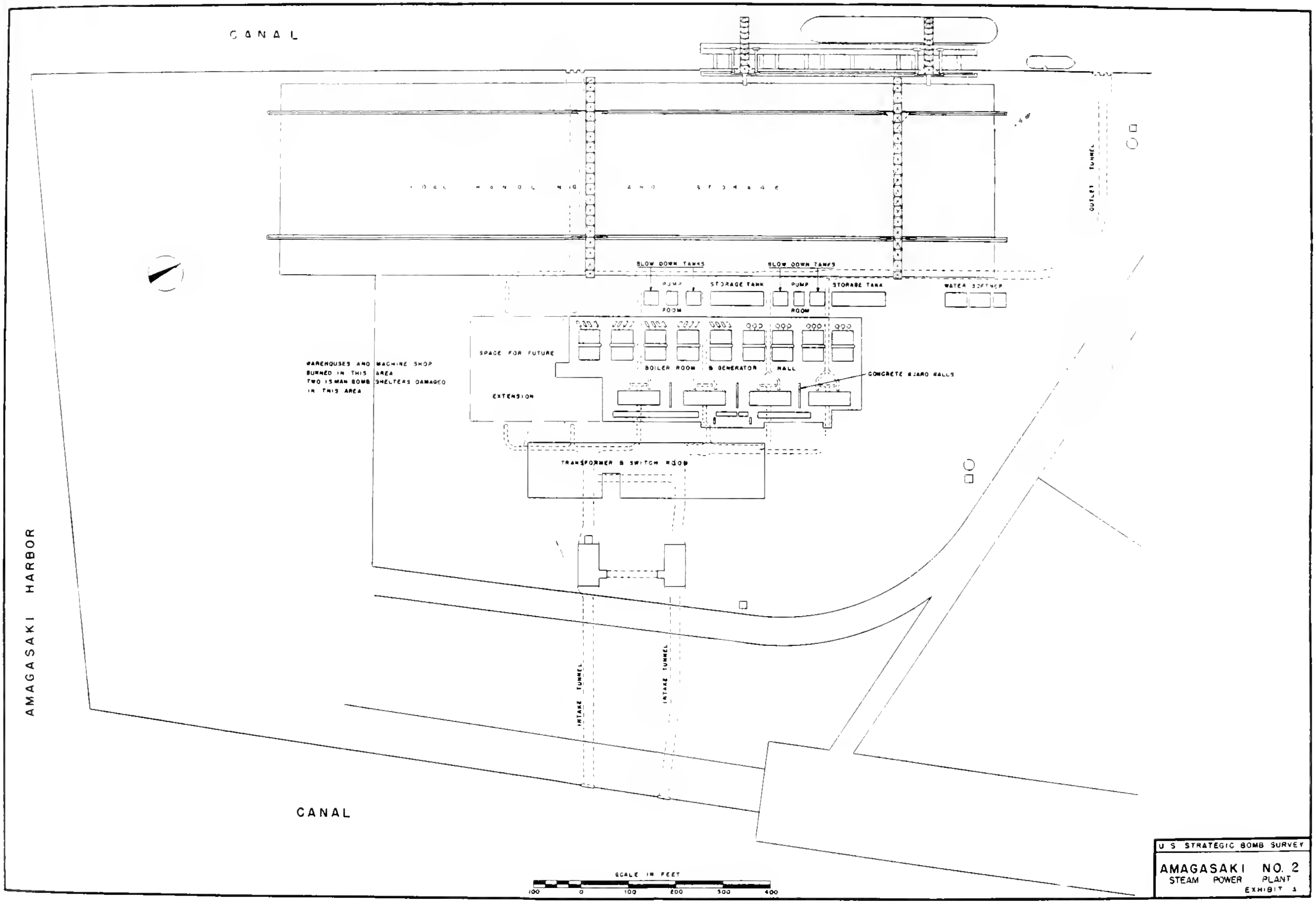
2. Record of the raid of 9–10 August 1945 in which this plant was severely damaged is covered in the report on raid 322, on Target 1203. Strike Attack Report No 138 mentions the fact that, "possible misidentification of the peninsula to the right of the target as the target itself may have caused the tendency in general towards that side," but no estimate of any kind was made of damage to this plant.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

The importance of this plant together with its two companion plants, Amagasaki No 1 and Amagasaki East, is most apparent. There was no other larger combine of steam power plants in Japan, and they were most important in the war economy.



CANAL
COAL HANDLING AND STORAGE
OUTLET TUNNEL
BLOW DOWN TANKS
PUMP ROOM
STORAGE TANK
BLOW DOWN TANKS
PUMP ROOM
STORAGE TANK
WATER SOFTNER
SPACE FOR FUTURE
EXTENSION
WAREHOUSES AND MACHINE SHOP BURNED IN THIS AREA
TWO 15 MAN BOMB SHELTERS DAMAGED IN THIS AREA
BOILER ROOM & GENERATOR HALL
CONCRETE GUARD WALLS
TRANSFORMER & SWITCH ROOM
INTAKE TUNNEL
INTAKE TUNNEL
AMAGASAKI HARBOR
CANAL
SCALE IN FEET
100 0 100 200 300 400
U S STRATEGIC BOMB SURVEY
AMAGASAKI NO. 2
STEAM POWER PLANT
EXHIBIT 1

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NO. 1
NO. 2
NIPPON OIL REFINERY
TANK FARM
N
POST STRIKE
TARGET 90.25-1203
13 AUG 1945
NIPPON OIL REFINERY &
TANK FARM-AMAGASAKI
20 AF-MISSION 322
9-10 AUG 1945
D.A. REPORT 191
U.S. STRATEGIC BOMBING SURVEY
AMAGASAKI STEAM
POWER PLANT NO. 2
EXHIBIT B

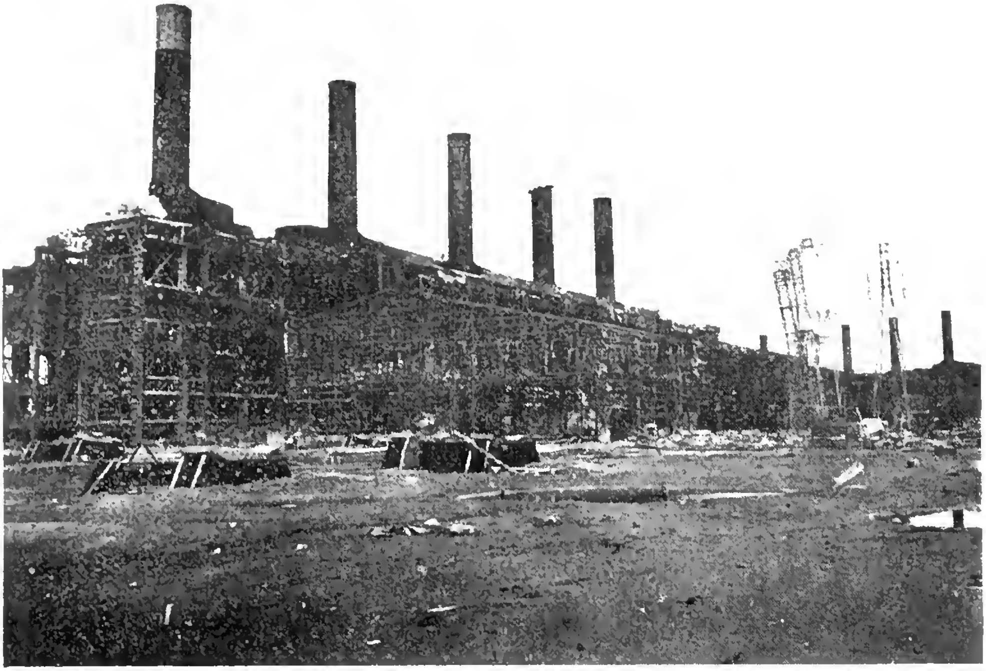


Photo 1—General view of plant looking north with part of building and stacks of Amagasaki in background at right

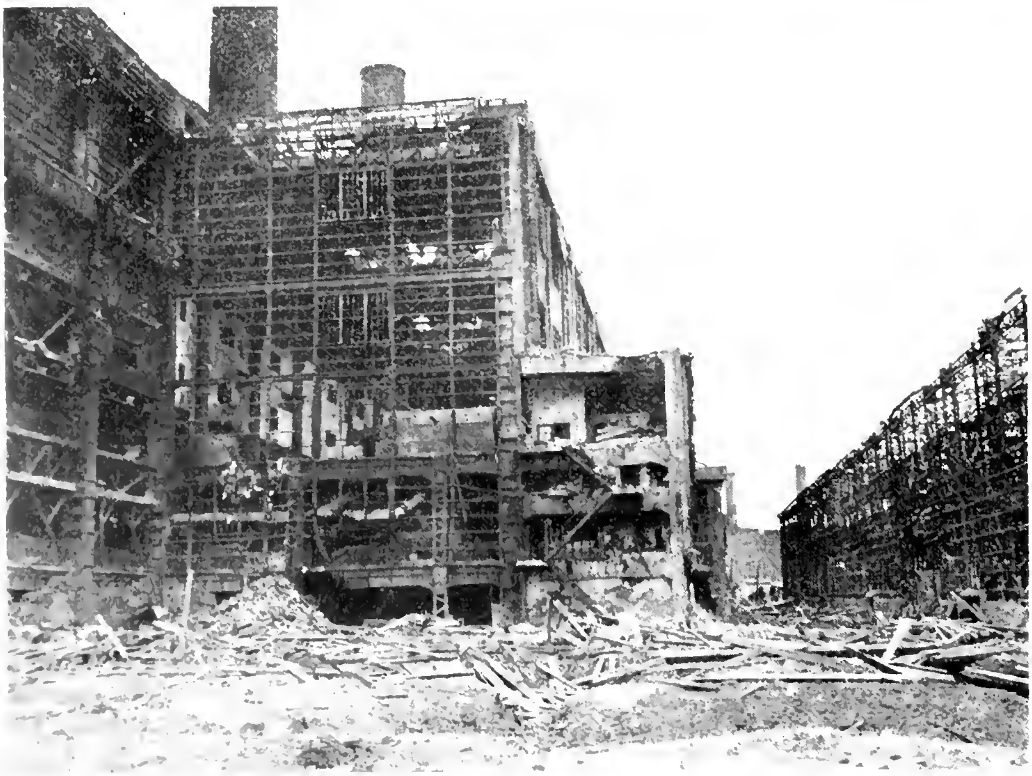


Photo 2—Closer view of damaged boiler, turbogenerator, and control section of plant at left and indoor transformer and switching building at right looking north

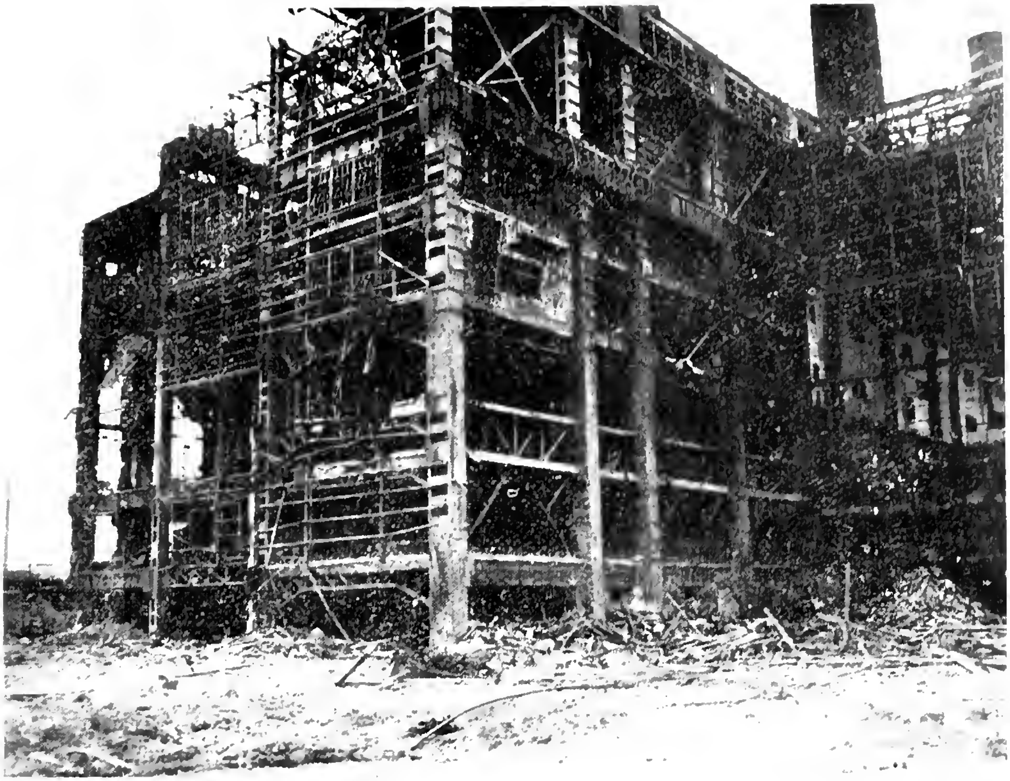


Photo 3—View of damaged south end of boiler house

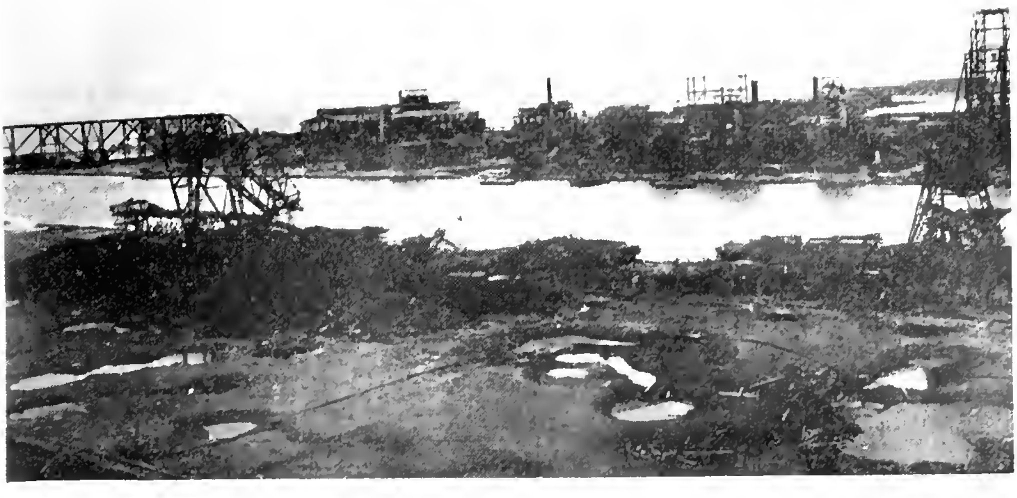
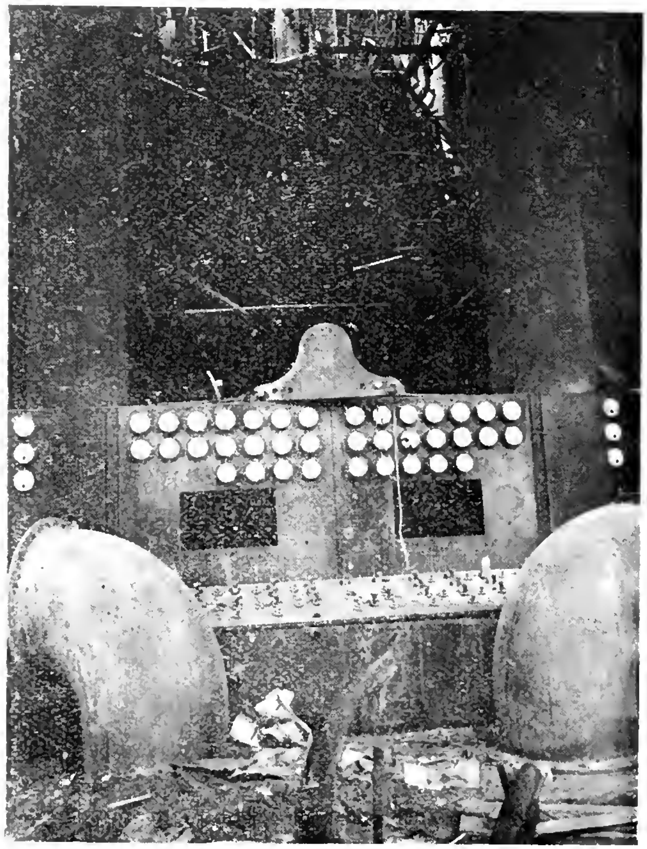


Photo 4—View looking west from top of boiler house showing damaged coal handling equipment with Nippon Oil Refinery across canal

Photo 5—View looking south of damaged boiler house roof

Photo 6—View of boiler No. 5 and 6 control



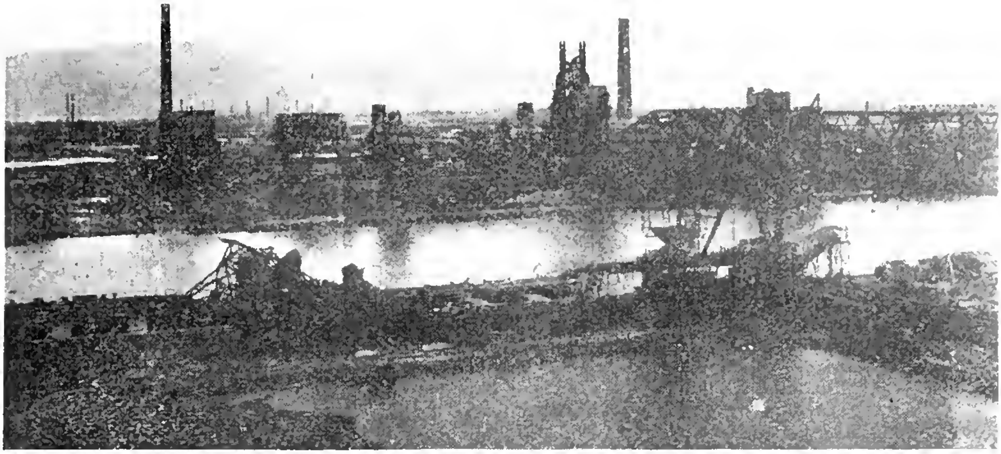


Photo 7—View looking north from top of boiler house showing damaged coal handling equipment with Nippon Oil Refinery across canal.

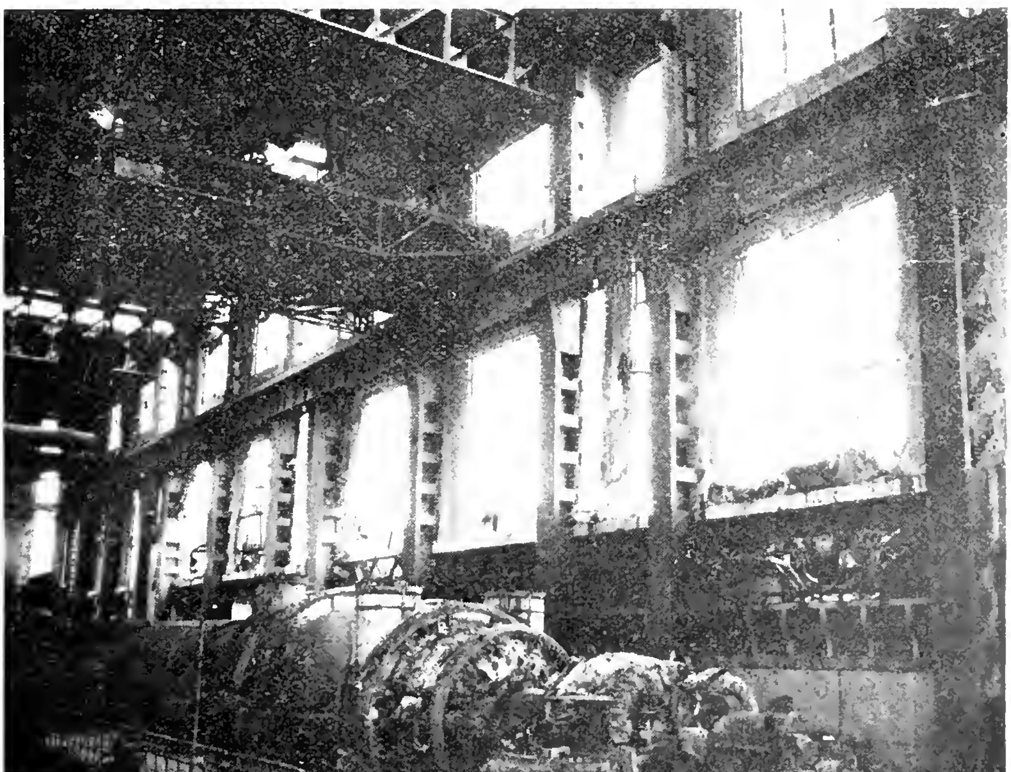


Photo 8—View showing damaged turbogenerator unit and building damage.

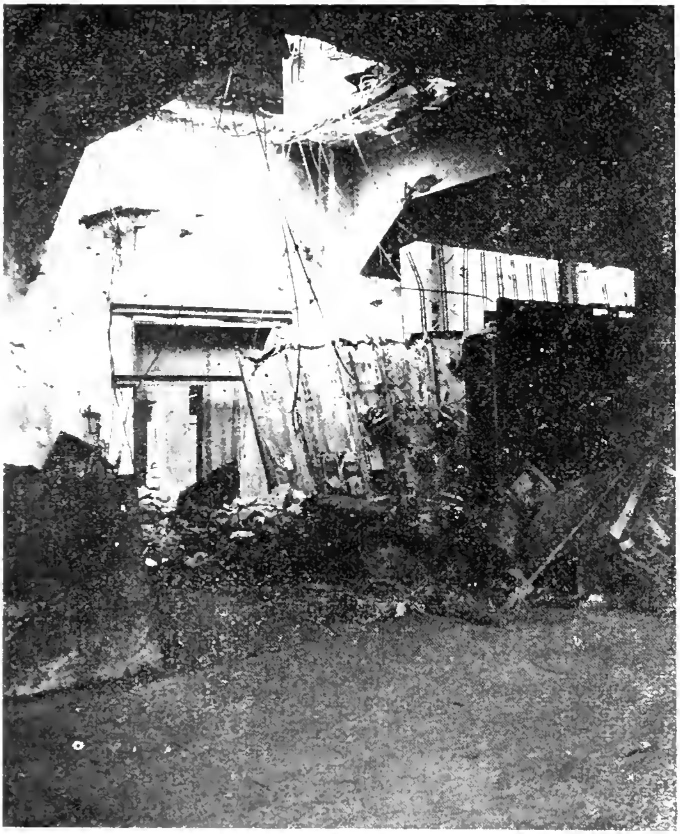


Photo 9—View of bomb hit in main control room

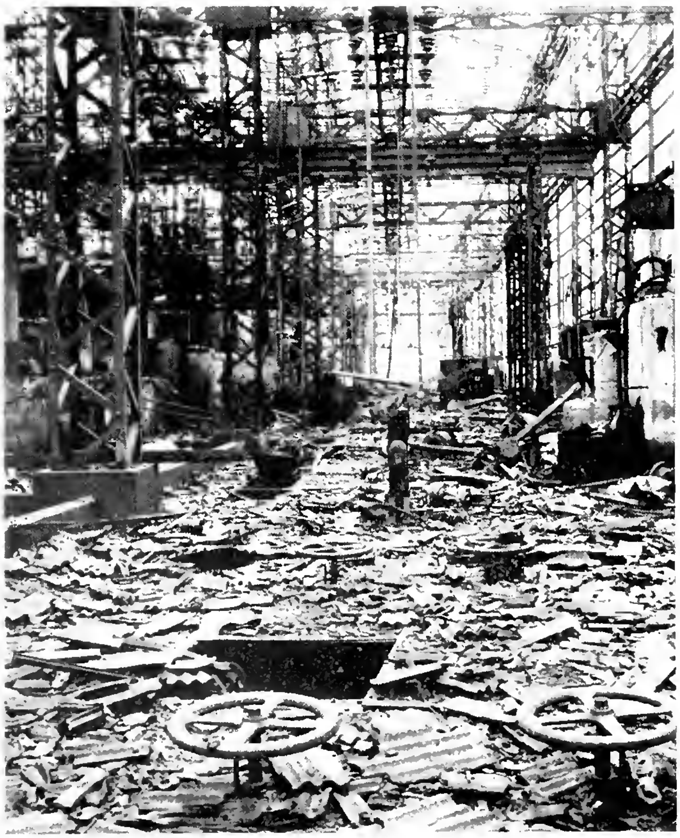


Photo 10—General view inside transformer and switching building

Photo 11—View of damaged oil circuit breaker

Photo 12—View of damaged transformers

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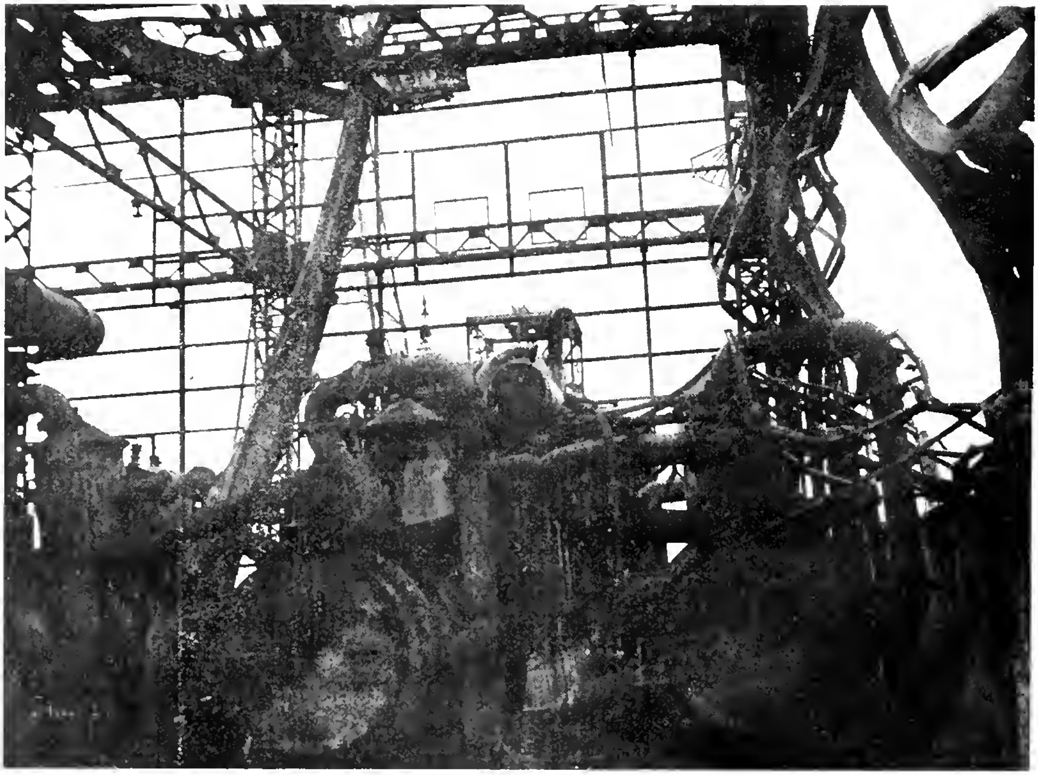


Photo 13—View of damaged oil coolers for main transformers, station transformer directly behind

EAST AMAGASAKI STEAM POWER PLANT

AMAGASAKI (NEAR OSAKA) JAPAN

DATE INSPECTED 30 OCTOBER 1945

Summary.

1. The East Amagasaki plant is located on Osaka Bay next to Amagasaki No. 1 and has 148,000 KW in name plate generating capacity. It is in a single large building with coal storage and handling equipment on one side and an outdoor substation on the other side. It was the tenth largest plant in Japan and third in the Osaka-Amagasaki-Kobe Area and an important plant in this highly industrial area especially during the dry winter season when hydro power was limited.

2. This plant was never a primary target nor was it subjected to any raids by the Twentieth AF, but was attacked 3 times evidently by carrier planes of the U. S. Navy. Although the plant was not damaged, warehouses in the plant area were burned, and the radiator of a transformer in the outdoor substation of the Kansai Electric Supply Co. located in the same plant area was damaged by gun fire.

3. No physical damage to plant except near hit on intake tunnel.

4. The size, importance, and location had been correctly evaluated in intelligence data.

5. This plant was one of the group composed of Amagasaki No 1, Amagasaki No 2, and Amagasaki East, all of which were located very close together. This combined group was by far the largest generator of electric energy in all Japan. Their output was approximately 1½ billion KWH in 1943 or 4 percent of all generation and almost 40 percent of the total generation of thermal plants. This was a factor of prime importance to the highly industrialized area in which they were located and to the war industry as a whole. Target information issued by the Joint Target Group had correctly summarized this situation but had not fully exploited the real significance or ease with which these plants could have been destroyed. It is very apparent that a splendid opportunity existed here to apply a relatively small expenditure of strategic bombing and achieve a remarkably destructive result.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The East Amagasaki plant is the third largest steam power plant in the Osaka-Amagasaki-Kobe Area and tenth largest in Japan. While it was principally used during the dry winter season operating between November through March, it also supplemented hydro power at other times of the year. Its annual output, maximum peak month output and maximum KW peak during the war years, was as follows:

Year	Annual Output KWH	Peak Month KWH	Peak KW
1942	158, 423, 100	32, 310, 700 (Nov.)	90, 000 (Dec.)
1943	134, 021, 300	38, 206, 100 (Dec.)	101, 200 (Dec.)
1944	108, 094, 400	30, 906, 100 (Jan.)	95, 000 (Jan.)
*1945	33, 019, 800	16, 625, 700 (Jan.)	85, 500 (Feb.)

*Two months only operation negligible since March 1945.

The output was supplied to the transmission network for general distribution with the majority utilized in the Osaka-Amagasaki-Kobe Area, both for base and peak loads.

2. Physical description of plant.

a. This plant is located approximately six-tenths of a mile northeast from Amagasaki No 1 on a tract of reclaimed land between Yomo and Shoge Rivers, on the northeast side of Amagasaki Harbor in Osaka Bay. (Exhibit A) Located in this same plant area is an outdoor substation stepping down from 77 KV to 11 and 22 KV belonging to the Kansai Electric Supply Co.

The plant area is trapezoidal in shape having a width of approximately 360 ft and extending back from a coal dock on the Shoge River approximately 500 ft with a total acreage of 4.25 acres. The main plant is in a reinforced concrete building approximately 250 ft long by 120 ft wide, the boiler and turbogenerator bays having a comparatively flat roof with ventilating louvers running full length. The control, electrical auxiliary equipment, and step-up transformers are located in a two floor annex, having a length the same as other bays but only about two thirds as high. There are 8 low steel stacks. Between the plant and coal dock are 2 coal storage yards with complete coal handling equipment.

The boiler room contains four 100,000-lbs/hr and four 138,000-lbs/hr stoker-fired, and four 115,000-lbs/hr and four 165,000-lbs/hr pulverized fuel fired boilers. The generator room contains 5 main turbogenerator units, of which 2 are 25,000-KW Metro-

politan Vickers, 2 are 25,000-KW Seimens Schuckert and 1 is a 40,000-KW Metropolitan Vickers. In addition, there are 2 turbogenerator units; one is a 7,000-KW Mitsubishi (Ljungstrum), and one is a 1,000-KW Metropolitan Vickers. Each main unit is connected directly to a step-up transformer bank which ties into the 77-KW system. The total name plate capacity of the plant is 140,000 KW in main generators and 8,000 KW in house generators.

b. The plant uses coal of approximately 11,520 Btu from Kyushu and Hokkaido. There was no shut down due to shortage of coal although at times the amount in storage was low.

3. The plant is owned and operated by the Japan Generation and Transmission Company, and the following were interviewed:

Mr. S. Kadono—Chief Engr. Kinki Branch.

Mr. S. Kaku—Generation and Transformation Engr, Kinki Branch.

Mr. N. Tsuchiyama—Steam Power Engr, Kinki Branch.

Mr. B. Saiki—Chief Engr of East Amagasaki Plant.

4. The plant normally used 230 employees during the war but at present is down to 150, operating on a 2 shift basis. Although operation of the plant is normally seasonal, their employees are used continuously with nonoperating period being devoted to maintenance.

Attacks.

According to plant personnel there were attacks on 15 June 1945, 5 August 1945, and 9 August 1945, records of which cannot be located in any reports of the mission file of the Twentieth AF. Therefore it is believed that these attacks were by carrier planes of the U. S. Navy.

Effects of Bombing.

1. Physical damage.

a. The damage was as follows:

(1) In the attack of 15 June 1945 there was strafing only. Damage was very slight, consisting only of the radiator of one transformer in an outdoor substation being punctured by a bullet. No fire was caused. Also, during this raid part of the adjacent Hanshin Electric Railway plant was strafed, but no damage resulted.

(2) In the attack of 5 August 1945 incendiary bombs burned the warehouses marked in Exhibit A.

(3) In the 9 August 1945 attack about 20 bombs fell just outside the plant area on the railroad tracks. One struck the intake canal but caused only minor damage and did not interfere with plant operations. Only minor protective measures had been taken.

b. Bomb plot and damage outline are shown in Exhibit A.

2. Production loss.

a. Production during the 3 war years averaged approximately 133 million KWH annually, but was negligible since March 1945 due to loss of demand through industry damage or diversion.

b. No substitution or modification necessary.

c. Causes for loss:

(1) There was no production loss from bomb or strafing damage.

(2) No loss of production was caused through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) No loss of production was caused through lack of fuel.

3. Recuperability cycle.

a. As no damage was done, there was no measure of recuperability obtainable.

4. Vulnerability.

The vulnerability of all steam power plants is fully covered in the final report which is fully applicable to this plant.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder 90.25 for Osaka Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as a target, correctly located it on maps, and evaluated its importance.

c. JTG information covered location of the plant on aerial photographs, but gave no further details.

2. Although this plant was attacked, it was not attacked by the Twentieth AF, and therefore no assessment report of damage is available.

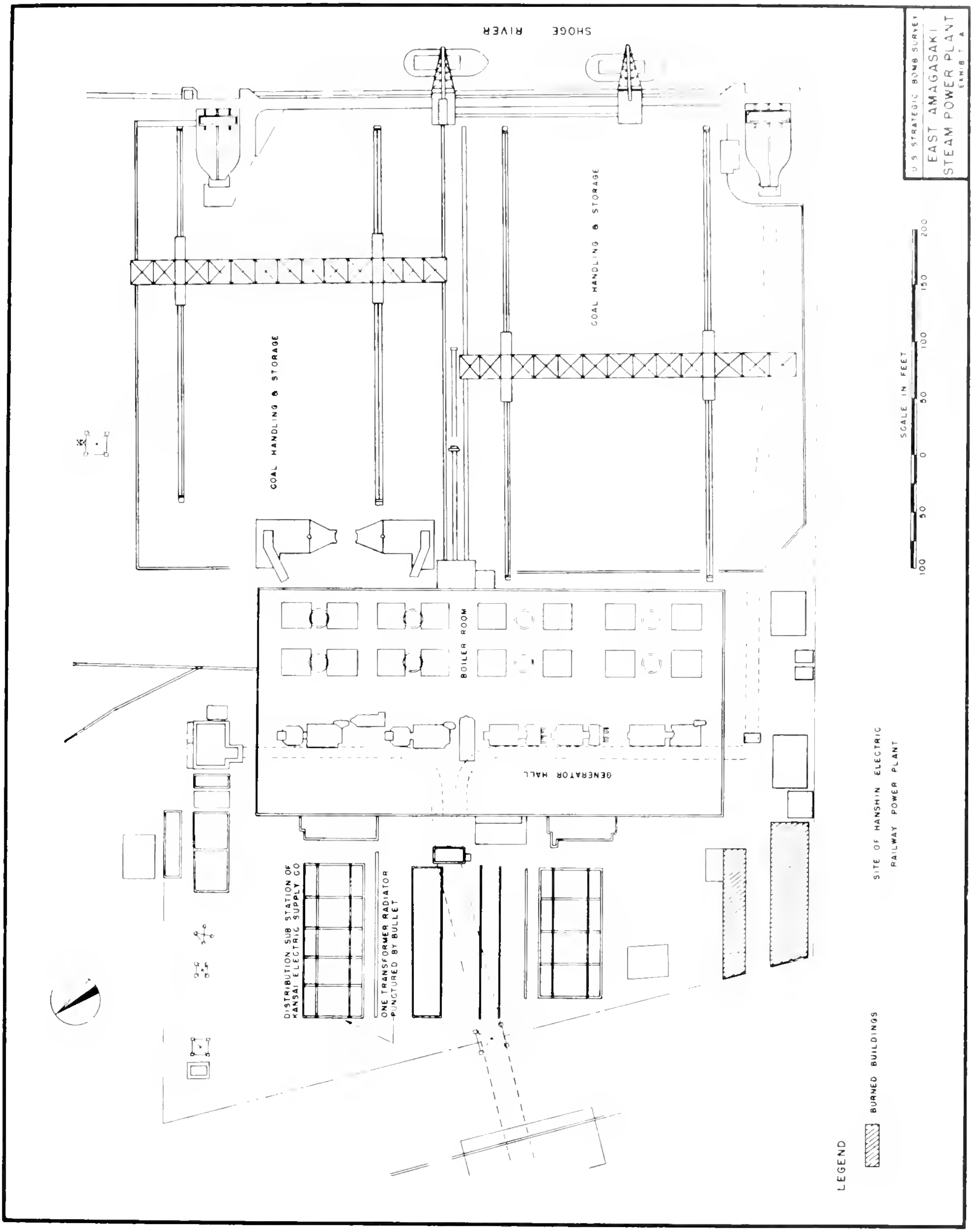
Data Relevant To Other Studies.

Amount of fuel in storage was low due to transportation difficulties.

Evaluations and Impressions.

This plant is located on reclaimed land and is settling at the rate of 3 to 4 in per year, and during a recent typhoon there was approximately 7 ft of water in the plant.

The importance of this plant together with its two companion plants, Amagasaki No 1 and Amagasaki No 2, is most apparent. There was no other larger combine of steam power plants in Japan, and they were most important in the war economy.


U S STRATEGIC BOMB SURVEY
EAST AMAGASAKI STEAM POWER PLANT
EXHIBIT A
SHOGE RIVER
COAL HANDLING & STORAGE
COAL HANDLING & STORAGE
BOILER ROOM
GENERATOR HALL
SCALE IN FEET
100 50 0 50 100 150 200
DISTRIBUTION SUB STATION OF KANSAI ELECTRIC SUPPLY CO
ONE TRANSFORMER RADIATOR PUNCTURED BY BULLET
SITE OF HANSHIN ELECTRIC RAILWAY POWER PLANT
LEGEND
BURNED BUILDINGS

PLANT REPORT NUMBER 7

KASUGADE STEAM POWER PLANT NO 1

OSAKA, JAPAN

DATE INSPECTED 28 OCTOBER 1945

Summary.

1. The Kasugade No 1, located at the junction of the Rokkenya and Aji Rivers, has a name plate capacity in turbogenerator units of 50,500 KW. The main plant is housed in a building having 4 hip-shaped bays, 2 of sheet steel on a steel frame, and 2 of reinforced concrete, with coal handling equipment on one side and coal storage on the other. It was rated 24th in Japan and 6th in Osaka-Amagasaki-Kobe Area, with an annual output averaging 22 million KWH during the three war years.

2. This plant was never a primary target. It was damaged slightly in a raid on the Osaka Urban Area by the Twentieth AF, on 1 June 1945. In the entire raid, 2890.7 tons of incendiary bombs were dropped with many falling in the warehouse and storage area between this plant and Kasugade No 2.

3. This plant proper suffered no physical damage. A number of warehouses burned causing loss of supplies and parts, but causing no production loss.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been correctly stated in damage assessment report.

5. While this plant, in itself, was not large nor particularly important, it was adjacent to Kasugade No 2, and the two plants together formed a target worthy of consideration. A raid could have been directed jointly against the two plants to achieve greatly desirable results.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The Kasugade No 1 plant was one of a number of important steam power plants in the Osaka-Amagasaki-Kobe Area and is ranked as 24th in Japan. While it was principally used during the dry winter season between November through March, it also supplemented hydro power at other times. Annual output, peak month, and peak load during the war years are as follows:

Year	Annual output KWH	Peak mo. KWH	Peak load KW
1942	33,316,800	9,895,200 (Aug.)	32,300 (Oct.)
1943	10,463,400	5,585,900 (Jan.)	32,600 (Mar.)
1944	22,382,800	10,407,800 (Feb.)	34,300 (Feb.)

Most of the output was supplied to the transmission net-work for general distribution with the majority utilized in the Osaka-Amagasaki-Kobe Area, both for base and peak loads. A small amount was furnished direct to consumers on local feeders.

2. Physical description of plant.

a. This plant is the lower or west one of two plants located at the junction of the Rokkenya and Aji Rivers in Osaka. It is approximately 920 ft from Kasugade No 2 with the intervening space extending from river to river occupied by warehouses and storage facilities, mostly of wooden construction, for both plants. (Exhibit A for plot plan and Exhibit B of Kasugade No 2 report for general plan of warehouses). The plant area between the two rivers is nearly rectangular in shape 555 ft by 150 ft between rivers with a total acreage of approximately 20 acres. The building consists of 4 hip-shaped roof bays, 2 running parallel for boilers and 2 perpendicular to rivers for turbogenerators and controls. The boiler house sections are of sheet metal over a steel frame; turbogenerator units are made of reinforced concrete with a 3 floor annex on the west for electrical control and auxiliary equipment, including house transformers. All roofs are made with covering over wood sheeting and all bays, except control, are provided with ventilating louvers running full length. The length of bays is approximately 145 ft, and widths of bays are: boiler 75 ft, turbogenerator 70 ft, and the annex 42 ft. There are a total of 8 reinforced concrete stacks arranged 4 in row parallel next to the turbogenerator bay, and 4 in a close rectangular group away from the boiler house at the west end and extending above the boiler house about twice the height of the bays. This is a peculiar arrangement that would be readily identified. The 2 barge or small vessel coal-unloading cranes are on the banks of the Aji River. Ashes are hauled out by manual labor. The boiler house contains 26 B&W type stoker-fired boilers, each of 38,000-lbs hrs maximum, continuous rating. Fourteen were installed in 1918, and 10 were installed in 1922. The generator bay contains 2 Ishikawajima 5,000-KW turbogenerator units installed in 1931 and one Hitachi 20,000-KW unit with a 500-KW house generator installed in 1937. The total name plant capacity is 50,000 KW in the main generators and 500 KW in the house unit. This station is tied to Kasugade No 2 by ten 11-KV underground

cables.

b. The plant uses coal of 11,520 Btu from Kyushu and Hokkaido. There were no shut downs due to lack of coal although at times the quantity in storage was low.

3. The plant is owned and operated by the Japan Generating and Transmission Co. and persons interviewed were:

Mr. S. Kadono—Chief Engr, Kinki Branch.

Mr. S. Kaku—Generation and Transmission Engr, Kinki Branch.

Mr. N. Tsuchiyama—Steam Power Engr, Kinki Branch.

Mr. S. Asade—Head master of Kasugade No 1 and No 2 steam power plants.

4. The plant normally uses throughout the year 93 employees on a 2 shift basis. Although operation of the plant is seasonal, the employees are used continuously with nonoperating periods being devoted to maintenance.

Attacks.

There were no primary attacks on this plant; however, warehouses were damaged during one raid on Osaka Urban Area, mission 187, on 1 June 45 at 1028 to 1200. Five-hundred and Six A/C of the 58th, 73rd, 313th and 314th Wings dropped 2890.7 tons of incendiary bombs from a height of 18,000 to 28,500 ft with 0/10—10/10 weather. This plant and companion plant, Kasugade No 2, were just at the edge of areas bombed.

Effects of Bombing.

1. Physical damage.

a. This plant suffered no physical damage. The bombs hitting in the area between Kasugade No 1 and 2 completely destroyed the warehouses and storage spaces, thus destroying spares and supplies. (Exhibit B report Kasugade No 2). The plant was shut down at the time of the raid. Protective measures taken were concrete shelters for employees at various points and some fire extinguishing equipment.

b. Due to the fact that incendiary bombs were dropped, no attempt had been made by plant personnel to make a bomb plot, so that a record of the actual number of bombs dropped into this warehouse and storage area could not be obtained.

2. Production loss.

a. There was no loss of production.

b. No substitution or modification was necessary.

c. Causes for loss:

(1) This plant suffered no damage.

(2) No production loss was caused through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) No loss from other causes except a reduction of output due to loss of load demand from industry, destruction, or dispersal.

3. Recuperability cycle.

None.

4. Vulnerability.

The vulnerability of all steam plants is fully covered in the final report which is applicable to this plant.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder No 90.25 for Osaka Area issued by Office of Assistant Chief of Air Staff, Intelligence, listed this plant as Target 323, correctly located it on map, evaluated its importance, but gave no plot plan. Photographic information, however, was correct.

c. JTG was essentially correct in listing this as a secondary standby power plant in the Osaka-Nagoya power system and gave the correct location on aerial maps which were too small to distinguish details of the plants.

2. Record of raid in which this plant was damaged is covered in reports on raids 187 on Osaka Urban Area.

Damage Assessment Report No 84, 10 June 1945, listed 10 small storage type buildings and 3 small buildings destroyed. These were in the area between this plant and Kasugade No 2 and were used for warehouse and storage. No report of damage was reported on the plant.

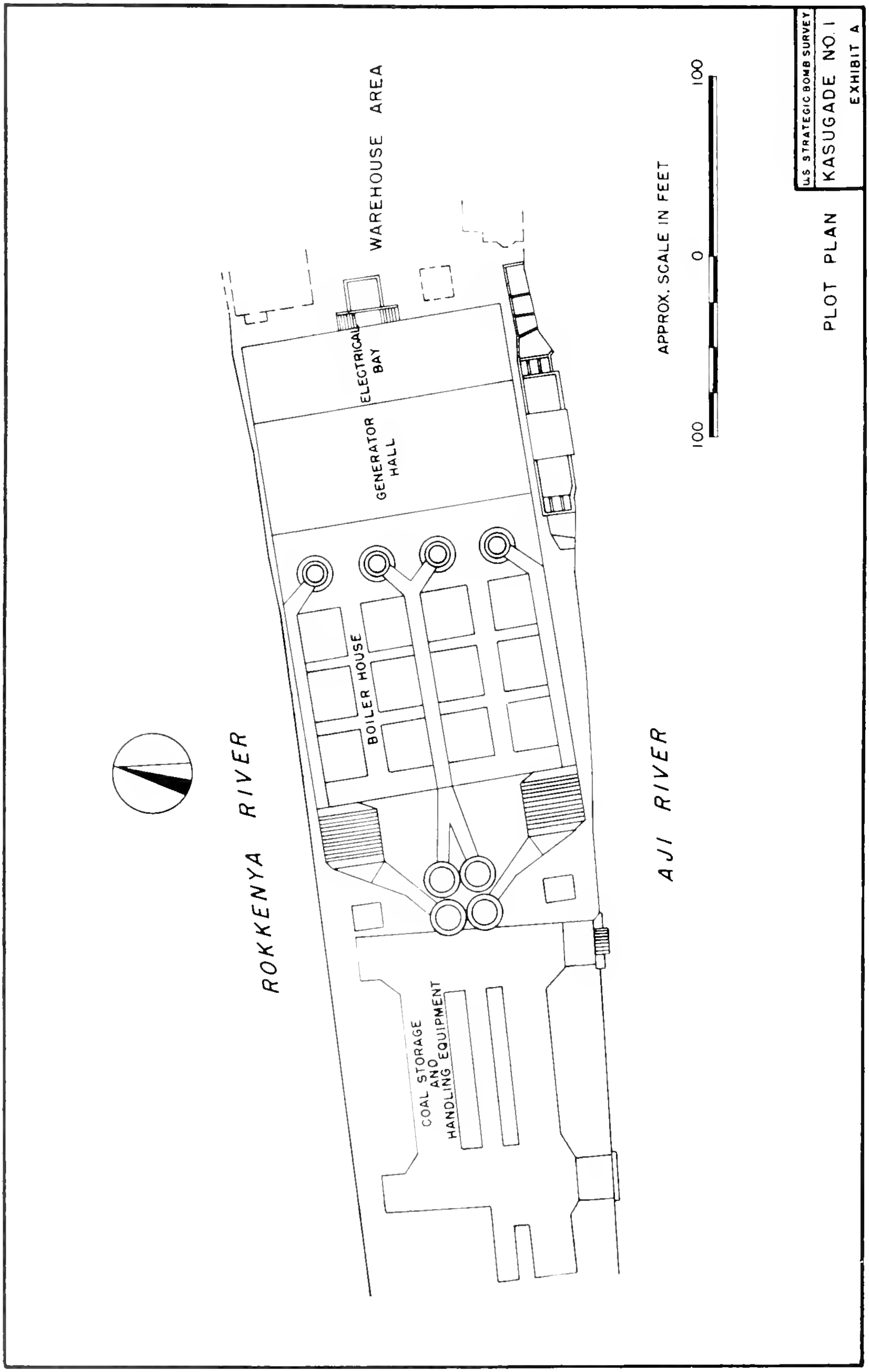
3. No mention was made in any damage assessment of recuperation or dispersal other than in report No 84, that warehouse or storage buildings were destroyed.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

This plant was an old plant and had a great many small capacity boilers operating at low pressure. It certainly would not be an efficient plant, which would reflect in turn on the amount of coal used and for which shipping space had to be provided. Normally such a plant would only be considered an emergency standby to be used only for taking care of a break down in service, and not for periods corresponding to the dry season.



U.S. STRATEGIC BOMB SURVEY
KASUGADE NO. 1
EXHIBIT A
PLOT PLAN
APPROX. SCALE IN FEET
100
0
100
WAREHOUSE AREA
ELECTRICAL BAY
GENERATOR HALL
BOILER HOUSE
COAL STORAGE AND HANDLING EQUIPMENT
ROKKENYA RIVER
AJI RIVER

PLANT REPORT NUMBER 8

KASUGADE STEAM POWER PLANT NO 2

OSAKA, JAPAN

DATE INSPECTED 28 OCTOBER 1945

Summary.

1. The Kasugade No 2, located at the junction of the Rokkenya and Aji Rivers, has a name plate capacity in turbogenerator units of 65,000 KW; however, when the last unit of 25,000-KW was installed, no additional capacity in boilers was added, so therefore, the plant capacity is nearer 40,000 KW. The main plant is located in a building having 3 hip-shaped bays, 2 of sheet steel on steel frames, and one of reinforced concrete with an annex of the same construction. It was rated 23rd in Japan and 5th in Osaka-Amagasaki-Kobe Area, with the annual output averaging 47 million KWH during the 3 war years.

2. This plant was never a primary target but was damaged on 1 June 1945 during a raid on Osaka Urban area by the Twentieth AF. In the entire raid, 2890.7 tons of incendiary bombs were dropped. A number of bombs fell on the wooden roof of the annex and the turbogenerator bay and in the warehouse and storage area between this plant and Kasugade No 1.

3. The principal physical damage was complete destruction of the main electrical control and various auxiliary panels, and control wiring on the top floor of the annex, with minor damage to insulators and a bushing in the outdoor substation. The plant was not in operation at the time of the damage, but at least one year's normal production loss was caused primarily due to fact that replacement material could not be obtained. No attempt at recuperation has been made. The vulnerability of steam power plants is fully shown due to the destruction of a portion rendering the entire plant inoperative.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been correctly stated in the damage assessment report.

5. While this plant in itself was not large nor particularly important, it was adjacent to Kasugade No 1, and the two plants together formed a target worthy of consideration. A raid could have been directed jointly against the 2 plants to achieve greatly desirable results. Although damage was caused by incendiary bombs, it was not indicative that this type of bomb is successful against power plants, as this particular plant was old and had a wooden roof, a type of construction that would never be used in a modern plant.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The Kasugade No 2 plant was one of a number of important steam power plants in the Osaka-Amagasaki-Kobe Area and is ranked 23rd in Japan. While it was principally used during the dry winter season between November and March, it also supplemented hydro power at other times. Annual output, peak month, and peak load during the war years are as follows:

Year	Annual output KWH	Peak mo. KWH	Peak load KW
1942	53, 551, 700	11, 923, 500 (Aug.)	41, 800 (Nov.)
1943	45, 021, 700	13, 533, 700 (Jan.)	46, 300 (Mar.)
1944	42, 296, 100	15, 941, 100 (Jan.)	41, 600 (Feb.)
*1945	2, 587, 900	2, 393, 700 (Feb.)	20, 400 (Feb.)

*No operation since March 1945.

The power was supplied to the transmission network for general distribution, with the majority utilized in the Osaka-Amagasaki-Kobe Area, both for base and peak loads.

2. Physical description of plant.

a. The plant is the upper or east one of 2 plants located at the junction of the Rokkenya and Aji Rivers in Osaka. It is approximately 920 ft. from Kasugade No. 1 with the intervening space extending from river to river occupied by warehouses and storage facilities, mostly of wooden construction for both plants. (Exhibits A and B for general plan of plants and warehouses) The plant area between the two rivers is trapezoid in shape running along the bank of the Aji River approximately 460 ft and the Rokkenya River 500 ft with a total acreage of approximately 45 acres. The building consists of 3 main, hip-shaped, roof bays, running parallel with the 2 for the boiler house of sheet metal over a steel frame and the one for the turbogenerator units of reinforced concrete, with a flat roofed, 3-floor annex on the west, about ⅔ the length of the bays, for electrical control and auxiliary equipment including

house transformers. All roofs are made with covering over wood sheeting, and all bays are provided with ventilating louvers running full length. The length of the bays is approximately 200 ft, and the widths of the bays are: boiler 100 ft, turbogenerator 50 ft, and the annex 14 ft. There are a total of 8 reinforced concrete stacks extending above the boiler house about twice the height of the bays. The two barge or small vessel coal unloading cranes are on the banks of Aji River on south side of the boiler house. Coal is carried by a conveyor direct to the bunkers above the stokers or by car to the storage yard on the opposite side of the plant. Ashes are hauled by car to barges on Rokkenya River.

The boiler house contains 32 B&W stoker-fired boilers, 26 of 33,000-lbs hrs and 6 of 38,000-lbs hr maximum continous rating. The generator bay contains two Westinghouse 20,000-KW turbogenerator units installed in 1922 and one Iskikawajima 25,000-KW unit installed in 1938. At the time of installation of this last unit, there was installed a bank of three 30,000-KVA, OISC transformers and an outdoor substation, stepping up to 77 KV for transmitting power to the Shinyodo River substation. This plant is also tied to Kasugade No 1 by ten 11-KV, underground cables. The total nameplate capacity is 65,000 KW.

b. The plant uses coal of 11,520 Btu from Kyushu and Hokkaido. There were no shut downs due to lack of coal, although at times the quantity in storage was low.

3. The plant is owned and operated by the Japan Generating and Transmission Co., and persons interviewed were:

Mr. S. Kadono—Chief Engr, Kinki Branch.

Mr. S. Kaku—Generation and Transmission Engr, Kinki Branch.

Mr. N. Tsuchiyama—Steam Power Engr, Kinki Branch.

Mr. S. Asade—Head master of Kasugade No 1, and No 2, steam power plants.

4. The plant normally uses throughout the year approximately 100 employees on a two shift basis. Although operation of the plant is seasonal, the employees are used continuously with nonoperating periods, being devoted to maintenance.

Attacks.

There were no primary attacks on this plant; however, it was damaged during one raid on Osaka Urban Area, mission 187, on 1 June 1945 at 1028 to 1200. Five-hundred and Ninth A C of the 58th, 73rd, 313th and 314th Wings dropped 2890.7 tons of incendiary bombs from a height of 18,000 to 28,500 ft with 0 10—10 10 weather. This plant and companion plant Kasugade No 1 were just at the edge of the area bombed.

Effects of Bombing.

1. Physical damage.

a. The physical damage to the plant proper was caused by incendiary bombs hitting the wooden roof of the annex and setting it on fire. Falling embers started a fire in an office on the third floor, then in the main control room, finally causing complete destruction of the control desk and various control panels and control wiring, putting the plant completely out of commission. (Exhibit C, photo No 1 and 2.)

Bombs hit the roof of the turbogenerator bay next to the boiler house and burned a large section of the roof, but did no other damage.

One bomb hit the outdoor substation, damaging the insulators of bus and disconnecting switches and of one bushing.

The balance of the bombs hitting in the area between Kasugade No 1 and 2, completely destroyed the warehouses and storage spaces, thus destroying spares and supplies. (Exhibit B)

Protective measures taken were concrete shelters for employees at various points and some fire extinguishing equipment.

b. Due to the fact that incendiary bombs were dropped, no attempt had been made by plant personnel to make a bomb plot, so that a record of the actual number of bombs dropped into this area could not be obtained.

2. Production loss.

a. The plant was not in operation at the time of the damage due to the loss of load from industry destruction, from dispersal and further due to the fact that the hydro power available was ample at the time to supply the requirements. Therefore, actual loss is not computable but based on average load for the previous 3 war years. It is estimated that a loss of 47 million KWH was sustained.

b. No substitution or modification was possible.

c. Causes for loss:

(1) The complete plant was rendered inoperative due to one particular damaged part, namely the main electrical control.

(2) No production loss was caused through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) No loss from other causes.

3. Recuperability cycle.

a. The only repair made had been the replacement of damaged roofs. Based on ability to secure required material and labor, it is estimated that complete repairs could be made in approximately 6 months; however, under available conditions, at least one year would be required.

b. No production had been reattained at the time of inspection.

c. No portion of the plant could have been utilized due to destruction of the portion essential to the entire plant operation.

4. Vulnerability.

The vulnerability of all steam plants is fully covered in the final report which is applicable to this plant. This is a particularly good example of the dependence of an entire plant on each part of its operating cycle.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder No 90.25 for Osaka Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as Target 323, correctly located it on the map, evaluated its importance, but gave no plot plan. Photographic information was correct.

c. JTG was essentially correct in listing this as a secondary standby power plant in Osaka-Nagoya power system and gave correct location on aerial maps which were too small to distinguish details of the plants.

2. A record of the raid in which this plant was damaged is covered in reports of raids 187 on Osaka Urban Area.

Damage Assessment Report No 84, 10 June 1945, listed 10 small storage-type buildings and 3 small buildings destroyed. These were in the area between this plant and Kasugade No 1 and were used for warehouse and storage. No report of damage was reported on the plant.

3. No mention was made in any damage assessment of recuperation or dispersal other than in report No 84, which states that warehouse or storage buildings were destroyed.

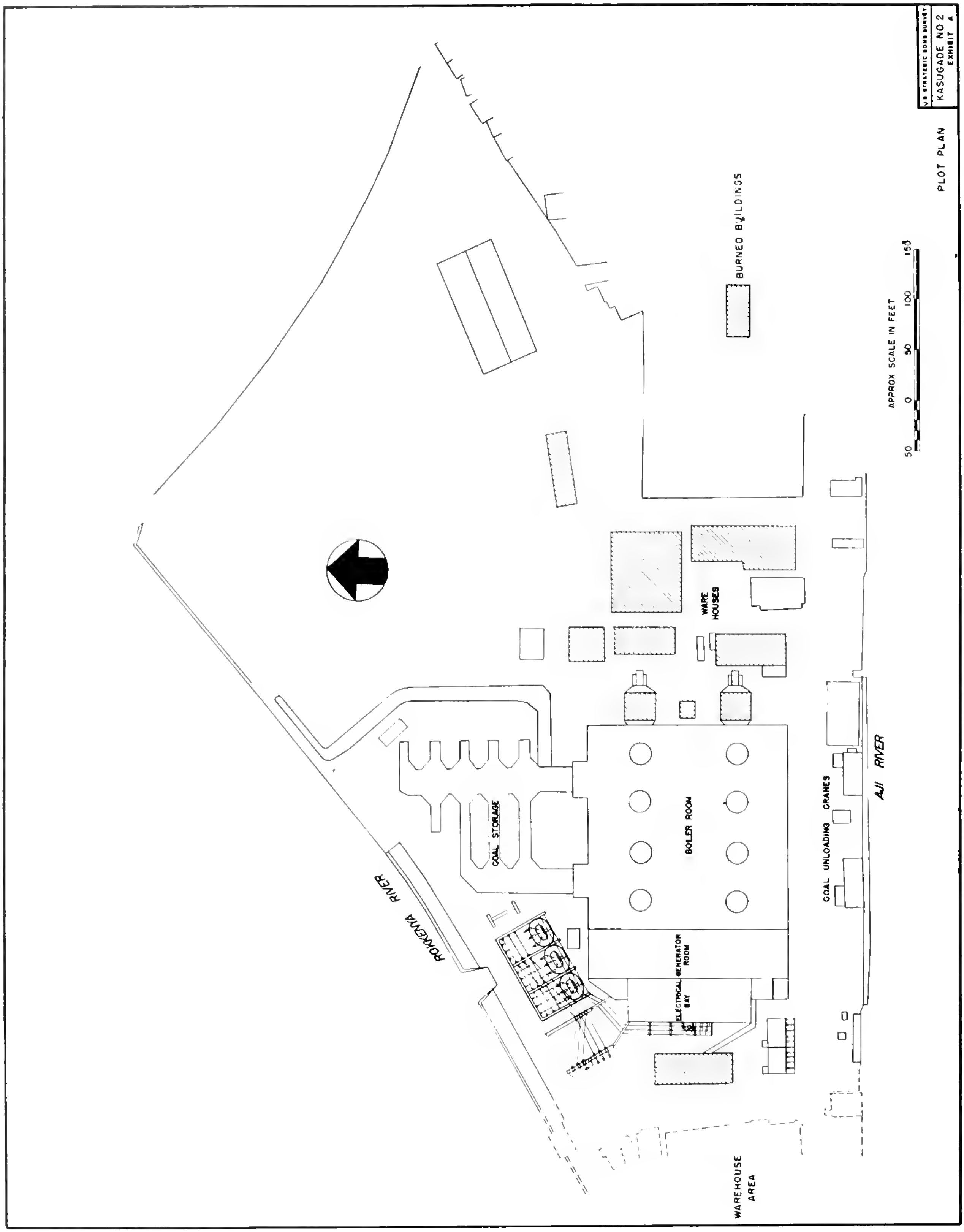
Data Relevant To Other Studies.

None.

Evaluations and Impressions.

This plant was an old plant and had a great many, small capacity boilers operating at low pressure. It certainly would not be an efficient plant, which would reflect in turn on the amount of coal used and for which shipping space had to be provided. Normally such a plant would only be considered an emergency standby to be used only for taking care of breakdown service and not for periods corresponding to the dry season.

The fact that this plant was seriously damaged from incendiary bombs should not be used as a criterion that this type of bomb is successful against power plants. This plant was old, and the type of wooden roof it had would never be used in a modern plant. Therefore, incendiary bombs are not recommended for use against power plants.


U S STRATEGIC BOMB SURVEY
KASUGADE NO 2
EXHIBIT A
PLOT PLAN
BURNED BUILDINGS
APPROX SCALE IN FEET
50 0 50 100 150
WARE HOUSES
COAL STORAGE
BOILER ROOM
COAL UNLOADING CRANES
AJI RIVER
ROKKENYA RIVER
ELECTRICAL GENERATOR ROOM
ELECTRICAL BAY
WAREHOUSE AREA

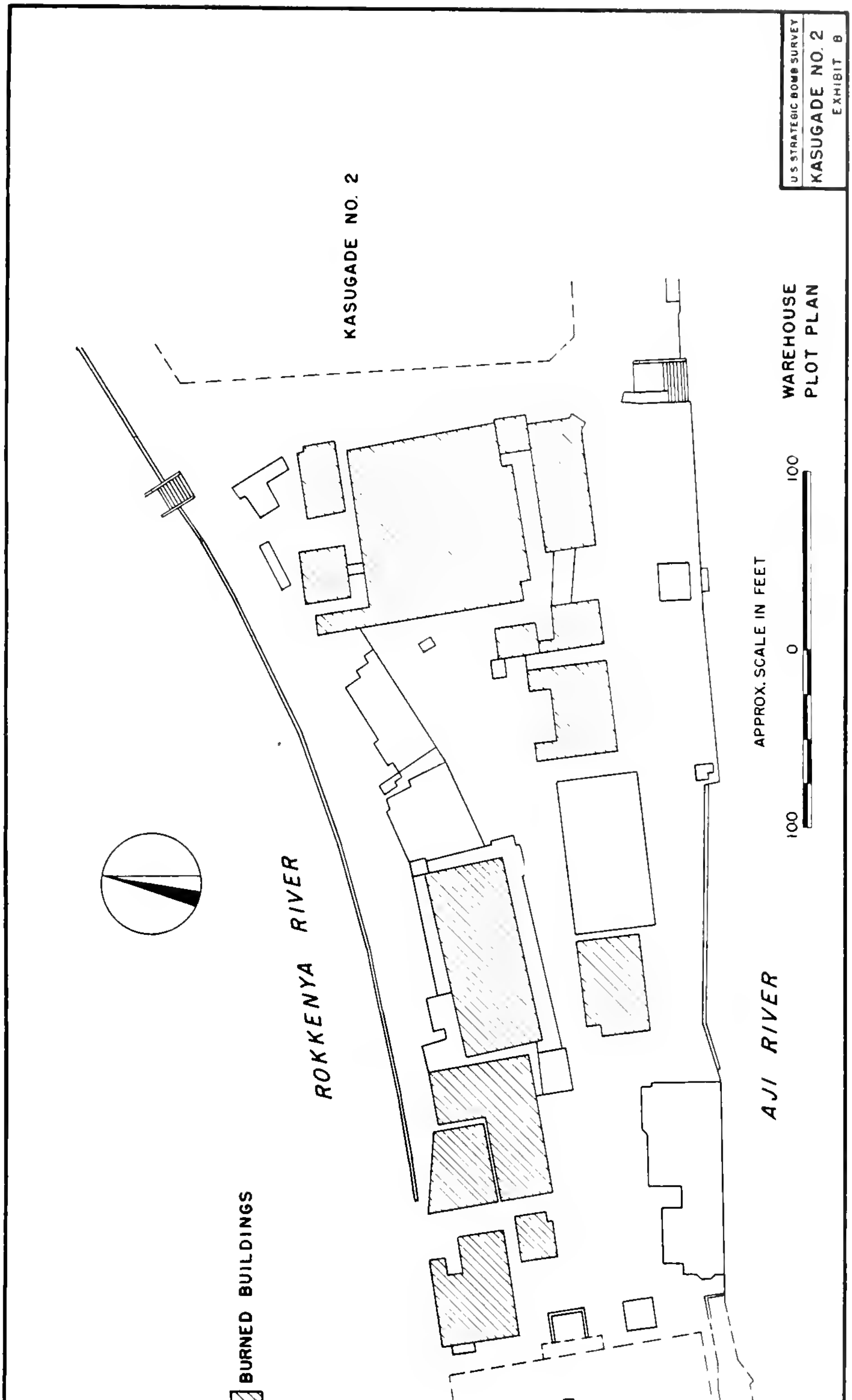

U S STRATEGIC BOMB SURVEY
KASUGADE NO. 2
EXHIBIT B
WAREHOUSE
PLOT PLAN
APPROX. SCALE IN FEET
100
0
100
KASUGADE NO. 2
ROKKENYA RIVER
AJI RIVER
BURNED BUILDINGS
KASUGADE NO. 1

EXHIBIT C

Photo 1—View showing damaged control desk and auxiliary panels and also damaged shelter

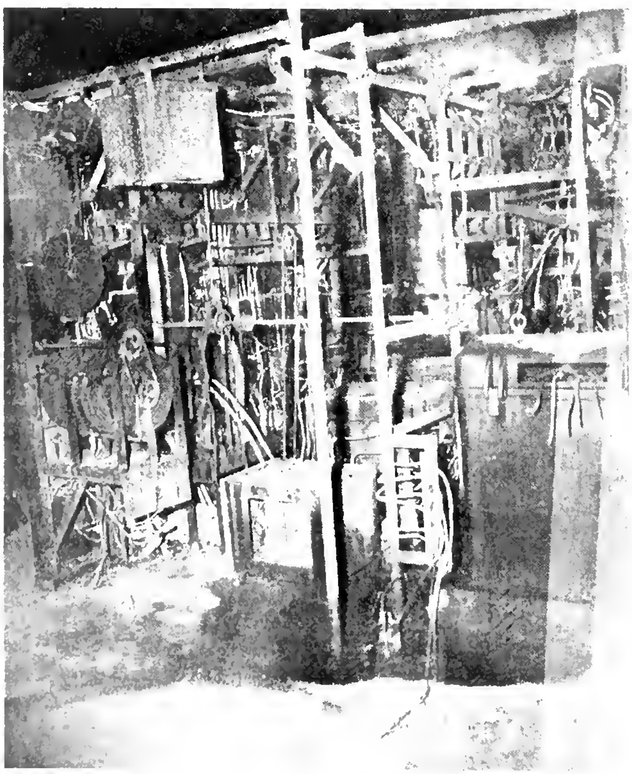


Photo 2—View showing rear view of damaged auxiliary panels

PLANT REPORT NUMBER 9

KAWASAKI STEAM POWER PLANT

KAWASAKI (NEAR TOKYO) JAPAN

DATE INSPECTED 18 OCTOBER 1945

Summary.

1. The Kawasaki Steam Power Plant, located on Tokyo Bay near Kawasaki, has 71,500 KW in name plate generating capacity. Main buildings are of concrete construction in two parts, the larger part containing plant power, with coal storage and handling equipment on one side, and the smaller part is the indoor transformer and high tension switching station. Its yearly output averaged in excess of 100 million KWH annually during the first 3 years of the war. It was 29th in size in Japan, and a very important standby plant for supply of power to the Imperial Japanese Government Railways especially during the dry season when hydro power was down.

2. This plant was never a primary target but was damaged in 3 raids on adjacent targets by the Twentieth AF. On 12 13 July 1945, 452 tons were dropped in the entire raid, and 4 bombs fell within the plant area. On 25 26 July 1945, 650 tons were dropped in the entire raid, and 57 bombs fell within the plant area. On 1 2 August 1945, 1017 tons were dropped in the entire raid, and 32 bombs fell within the plant area.

3. The principal physical damage was the complete destruction of coal handling equipment and collapse of the circulating water intake tunnel which put the plant completely out of commission. In addition, damage was done to the steam end of No. 3 turbogenerator unit, to generator cables and control bay. Although the plant was not in operation at the time of the damage, the loss of production is equivalent to at least 50 percent of one year's normal production or 57 million KWH. No attempt at recuperation has been made. The vulnerability of steam power plants is fully shown since the destruction of a portion rendered the entire plant inoperative for a long period of time.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been correctly stated in damage assessment reports.

5. Of significance at this plant is the apparent ease with which a steam power plant can be rendered inoperative by a small tonnage per acre.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The Kawasaki plant was the largest steam power plant for power supply to the electric railways in and around Tokyo. While it was used principally during the dry winter season between November and March, it also supplemented hydro power at other times of the year. Its output for 1941, which is the only record available as the others had been lost due to air raids, is as follows:

Months	KW Hrs. per mo.	Months	KW Hrs. per mo.
Jan	11,964,200	July	6,141,000
Feb	12,521,400	Aug	7,072,200
Mar	12,238,600	Sept	6,468,300
Apr	11,191,000	Oct	7,810,000
May	8,924,600	Nov	13,027,200
June	6,123,050	Dec	10,570,900
		Total	114,052,450

2. Physical description of plant.

a. The plant is located on the Kawasaki water front on the NW side of Tokyo Bay, on the west side of the third large block of reclaimed land 3.5 miles SW of the Tama River mouth and about 2.25 ENE of the Tsurumi River mouth. The compound is on the East bank of a 600-ft wide ship canal and just north of the Mitsubishi wharfs, warehouses, and coal depot, Target 191, and Mitsubishi Piece Goods wharf and warehouses, Target 1437. In the same block of reclaimed land are located other important industrial plants, such as the Japan Steel Tube Co., Target 52, Mitsubishi Oil Refinery, target 116, Hayama Petroleum Refinery, Target 127, and Showa Fertilizer, target 137. Nearly directly across the canal is located the Tsurumi Steam Plant, Target 110 and NW across the canal is located the Ushioda Steam Power Plant, Target 493.

The main plant area is rectangular in shape, the east-west dimension being approximately 650 ft and the north-south dimension 600 ft with a total acreage of 9 acres. In addition warehouses, quarters, shelter, etc., are located on an approximately triangular plot extending approximately 700 ft east. (Exhibit A)

The main buildings are of reinforced concrete in 2 separate parts. The larger section contains the

boilers and turbogenerator units and main electrical control and auxiliary equipment in a 3-floor section, and the smaller section, also 3 floors, contains the main step-up transformers, house transformers, and 66-KV switch gear. The two parts are connected by a narrow multifloor office building. The space between the parts is occupied by water tanks and transformer repair building with track for transfer of transformers. There are 8 steel stacks, but they are not tall or particularly visible. (Exhibit B, photo No 1) The plant area is adjacent to a 600 ft canal, and between the main buildings and this canal is a large coal storage and handling yard which is readily identifiable.

The boiler room contains eight 88,000-lb/hr rating boilers on the basis of 11,340 Btu coal. Four are B&W Stirling type with pulverized fuel-burning equipment, and 4 are Mitsubishi Stirling type with stokers. The generator room contains 2 Mitsubishi 25,000-KW turbogenerator units, one BTH 20,000-KW turbogenerator and a 1,500-KW house unit totalling 71,500 KW in name plate capacity. The generators are connected directly to their own bank of single-phase, step-up transformers with all switching done on the high voltage side.

b. The plant normally used coal of approximately 11,340 Btu that was received by ship from Kyushu and Hokkaido, but during the war period it was necessary to obtain coal from Taira, 100 km N. of Tokyo. This coal had only approximately 7,200 Btu thus reducing the capacity of the plant to two-thirds of normal.

3. The plant is owned and operated by the Imperial Government Railways, and information was obtained from Mr. K. Kamatsu, Chief Engineer.

4. The plant normally uses 290 employees but recently has been down to 200 operating on the basis of two shifts. Although operation of the plant is normally seasonal, the employees are used continuously during nonoperating periods which are devoted to maintenance.

Attacks.

The plant was never a primary target; however, it was damaged during three raids directed against adjacent targets. The first damage was on 12/13 July 1945 during a night attack on Kawasaki Petroleum Center, Mission 267 of the Twentieth AF, when 53 A/C of the 315th Wing dropped 452 tons of 500-lb GP bombs fused 1/10 second nose, and 1/40 second tail, from a height of approximately 16,000 ft with 8/10–10/10 weather. In this raid 4 bombs fell within the plant area; one fell in the coal yard, and one hit the building. The second damage occurred on 25/26 July 1945 during a night attack on Hayama Petroleum Refinery and Mitsubishi Oil Refinery, Mission No. 291 of the Twentieth AF. Seventy-Fifth A/C of the 315th Wing dropped 650 tons of 500-lb GP bombs fused 1/10 second nose, and 1/40 second tail, from a height approximately 17,000 feet with weather from 0/10 to 10/10. In this raid 57 bombs fell in the plant area of which 9 hit or hit near buildings close enough to cause damage, 32 hit the coal yard and coal handling equipment, and 3 hit the intake tunnel. The third damage was on 1/2 August 1945 during a night attack on the Kawasaki Petroleum Center, the Hayama Petroleum Refinery, and the Mitsubishi Oil Refinery, Mission No. 310 of the Twentieth AF. One-Hundred and Twentieth A/C of the 315th Wing dropped 1017 tons of 500-lb GP bombs fused 1/10 second nose, and 1/40 second tail, from a height of approximately 17,500 ft with 8/10—10/10 weather. In this raid 32 bombs fell in the plant area of which 20 hit or hit near buildings close enough to cause damage and 1 hit near the intake tunnel.

Effects of Bombing.

1. Physical damage.

a. (1) The damage on 12/13 July 1945 was as follows:

One bomb hit damaged skip hoist control panel.

One bomb hit in the coal yard doing little damage.

(2) The damage on 25/26 July 1945 was as follows:

Thirty-two bombs hit on coal handling equipment causing heavy damage. (Exhibit B, photos No 2 and 3)

Three direct bomb hits on boiler room as follows:

Boiler No 6—hit wall opposite doing no damage to boiler.

Boiler No 3—direct hit on induced fan completely destroying it.

Boiler No 7—direct hit on steam header causing medium damage.

Three bomb hits on the skip hoist caused severe damage (Exhibit B, photo No 4).

Two bomb hits on the turbogenerator bay.

One bomb hit building causing medium damage.

One bomb hit turbine floor near the high pressure end of unit No 3 cutting and destroying a heavy floor girder, damaging a stop valve, instruments, and causing severe fragmentation damage to unit No 3 and damaged the exciter of unit No 2. (Exhibit B, photo No 5)

Three bomb hits on circulating, water, intake tunnel causing collapse.

One bomb hit in an open space between the turbo-

generator bay and the transformer bay back of the office section damaging cable connection between generator No 3 and the corresponding transformer bank as well as damaging the transformer transfer track. (Exhibit B, photo No 6).

(3) The damage on 1/2 August 1945 was as follows:

One bomb hit the coal storage.

Two bomb hits near the skip hoist. (Exhibit A and Exhibit B, photo No 4)

Five bomb hits on the boiler room as follows:

Boiler No 3—damaged roof but boiler not damaged.

Boiler No 8—detonated near roof damaging coal bunker.

The other 5 bomb hits did minor damage to coal bunkers and light structures.

Two bomb hits on control bay:

One destroyed voltage regulator and auxiliary control panel for unit No 3.

One damaged building only.

Seven bomb hits on the transformer and high tension bay.

Six bombs detonated in the upper floors causing medium damage to the building and bus connections and instrument transformers.

One bomb hit the outside wall causing little damage.

One bomb hit the transformer repair shop damaging the wall but nothing else.

The warehouse area was severely bombed as shown on bomb plot (Exhibit A) resulting in destruction of many buildings containing spares and operating supplies. Twenty-two persons were killed in a bomb shelter which received a direct bomb hit.

Balance of the bombs did minor damage throughout the area. The 2 bomb shelters were the only protective measures taken.

b. Bomb plot (Exhibit A) furnished by plant personnel.

2. Production loss.

a. This plant produced 114,052,450 KWH in 1941 which increased for 1942, then began declining and reached a maximum drop of 30 percent. This variation was due in part to seasonal demands dependent on the supply of hydro power and in part to the quality of coal obtained, especially during the latter part of the war. The plant was not operating at the time of the various bomb damage dates as this power was not needed at that time since hydro power was available. Also power demands were down because of the loss of load which resulted from the fact that a large number of electric cars were lost in area bombing and that industrial plant dispersal had reduced the number of passengers. However, it is reasonable to assume that the loss of production would have been at least one season's normal production of ½ of that produced in 1941 or about 57,000,000 KWH.

b. No substitution or modification was possible.

c. Cause of loss:

(1) The entire plant was rendered completely inoperative due to 2 main items of damage, namely, destruction of coal handling equipment and destruction of the circulating water, intake tunnel, plus other damage.

(2) No production was lost through diversion of labor, material, and machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused by absenteeism or unusual inefficiency.

(5) A loss of production was caused throughout the war because of the poor grade of coal used and because of the lack of transportation for better coal.

3. Recuperability cycle.

a. No repairs had been made or even started, not even repairing the building to protect indoor equipment from weather. Based on ability to secure required materials and skilled labor, it is estimated that complete repairs could have been made and the plant put back in operation as follows:

(1) From damage of 13/14 July 1945 repairs would require 1 week.

(2) From damage of 25/26 July 1945 repairs would require 3 months.

(3) From damage of 1/2 August 1945 repairs would require 6 months.

b. No production had been reattained at the time of inspection.

c. No portion of the plant could have been utilized because of the destruction of portions essential to the entire plant.

4. Vulnerability.

The vulnerability of all steam power plants is fully covered in the final report which is particularly applicable to this plant.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder 90.17 for Tokyo Area issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as Target 111, correctly located it on maps, evaluated its importance and gave a correct plot plan and photographic information.

c. JTG information was correct. Aerial photographic cover was excellent and location of buildings

correct. The size of the plant area given was slightly in error and weapon recommendation was not concurred in.

2. Records of the raids in which this plant was damaged are covered in raid report 267, 291, and 310 on targets 116 127, and 128.

a. Damage Assessment Report No. 157, covering raid on 12 13 July 1945 does not list any damage to this plant.

b. Damage Assessment Report No. 173, covering raid of 25 26 July 1945 and 1 2 August 1945 lists the total damage severe.

c. Damage Assessment Report No 184, covering raid on 1 2 August 1945 does not list any damage to this plant, although aerial photographs if taken would have shown additional strikes.

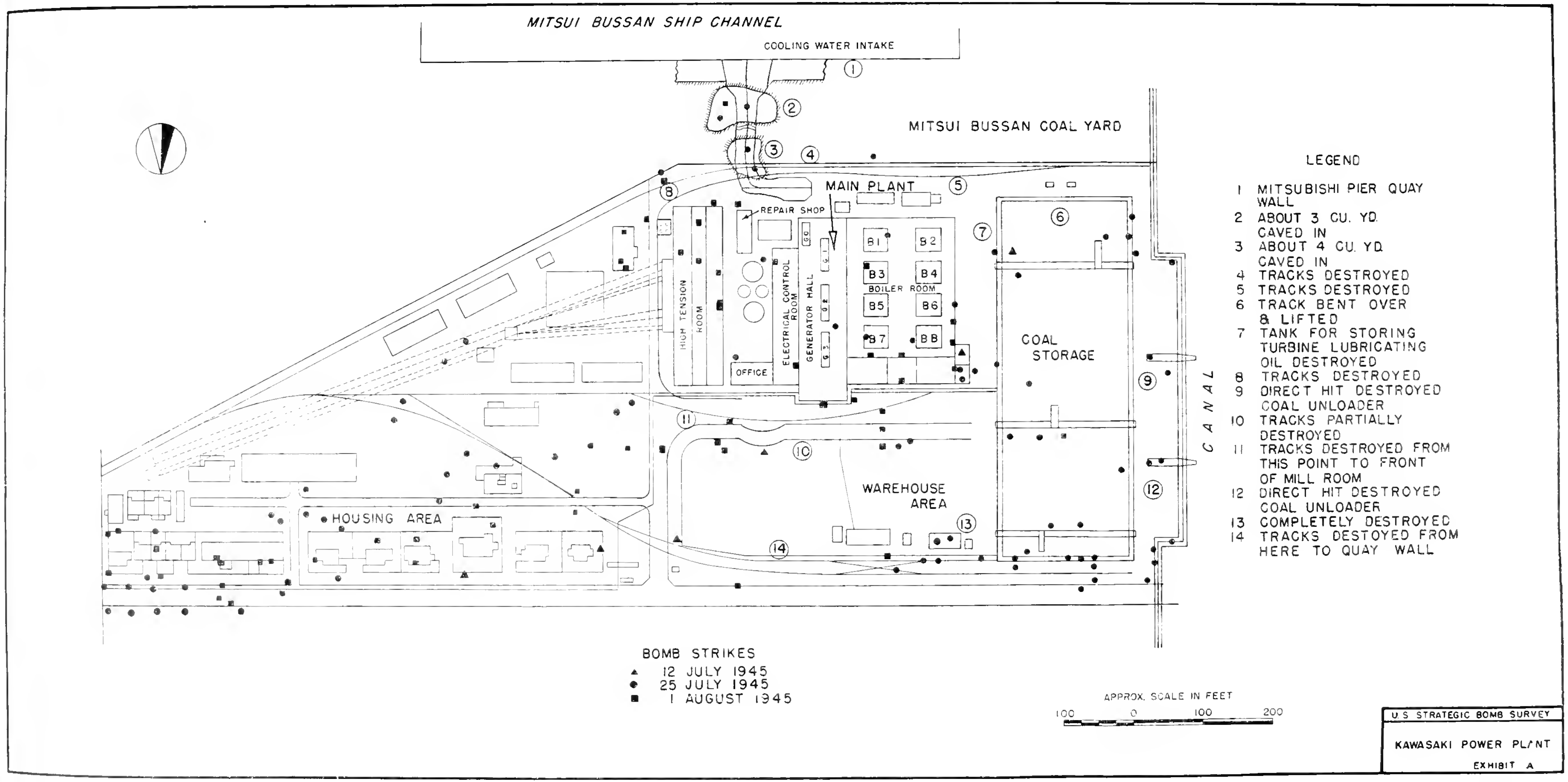
3. No mention was made in any damage assessments of recuperation or dispersal other than to mention in Report No 173 that the total damage was severe.

Data Relevant To Other Studies.

The shortage of coal and necessity of using poor grade coal was due to transportation difficulties, especially the curtailment of ship transportation of coal.

Evaluations and Impressions.

This plant is a typical example of general steam plant operation which is not up to standards of similar plant operations in the U.S. No effort had been made at the time of inspection to clean up damage or even repair bomb holes in the roof or replace broken windows. The skip hoist design and concentration at one point made it very vulnerable, and the plant was put out of commission by damaging this alone.


MITSUI BUSSAN SHIP CHANNEL
COOLING WATER INTAKE
MITSUI BUSSAN COAL YARD
MAIN PLANT
REPAIR SHOP
HIGH TENSION ROOM
ELECTRICAL CONTROL ROOM
GENERATOR HALL
OFFICE
B1
B2
B3
B4
BOILER ROOM
B5
B6
B7
B8
COAL STORAGE
CANAL
WAREHOUSE AREA
HOUSING AREA
LEGEND
1 MITSUBISHI PIER QUAY WALL
2 ABOUT 3 CU. YD. CAVED IN
3 ABOUT 4 CU. YD. CAVED IN
4 TRACKS DESTROYED
5 TRACKS DESTROYED
6 TRACK BENT OVER & LIFTED
7 TANK FOR STORING TURBINE LUBRICATING OIL DESTROYED
8 TRACKS DESTROYED
9 DIRECT HIT DESTROYED COAL UNLOADER
10 TRACKS PARTIALLY DESTROYED
11 TRACKS DESTROYED FROM THIS POINT TO FRONT OF MILL ROOM
12 DIRECT HIT DESTROYED COAL UNLOADER
13 COMPLETELY DESTROYED
14 TRACKS DESTOYED FROM HERE TO QUAY WALL
BOMB STRIKES
▲ 12 JULY 1945
● 25 JULY 1945
■ 1 AUGUST 1945
APPROX. SCALE IN FEET
100 0 100 200
U.S. STRATEGIC BOMB SURVEY
KAWASAKI POWER PLANT
EXHIBIT A

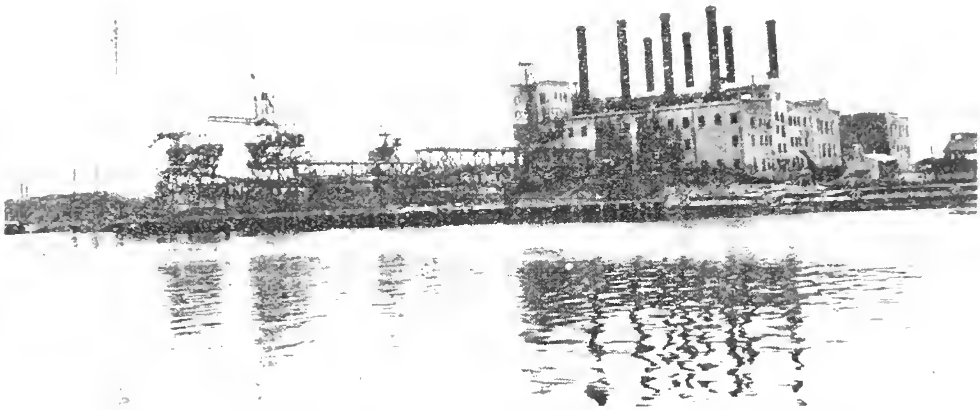
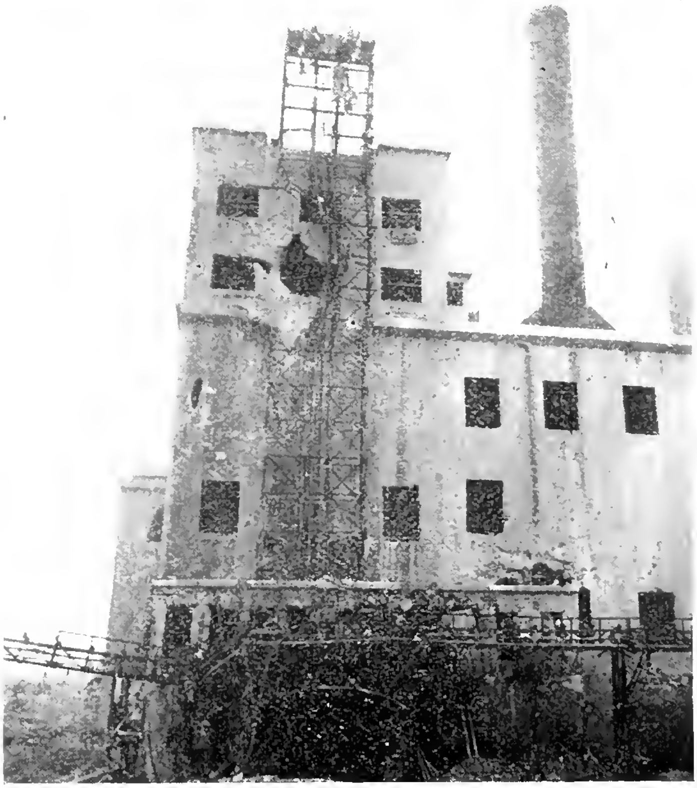


Photo 1—General view of plant looking northeast from Tsurumi plant across 600 ft canal

Photo 2—View of damaged unloading crane and conveyors

Photo 3—View of damage to traveling gantry crane in coal yard

Photo 4—View showing damaged skiphoist and coal conveyor



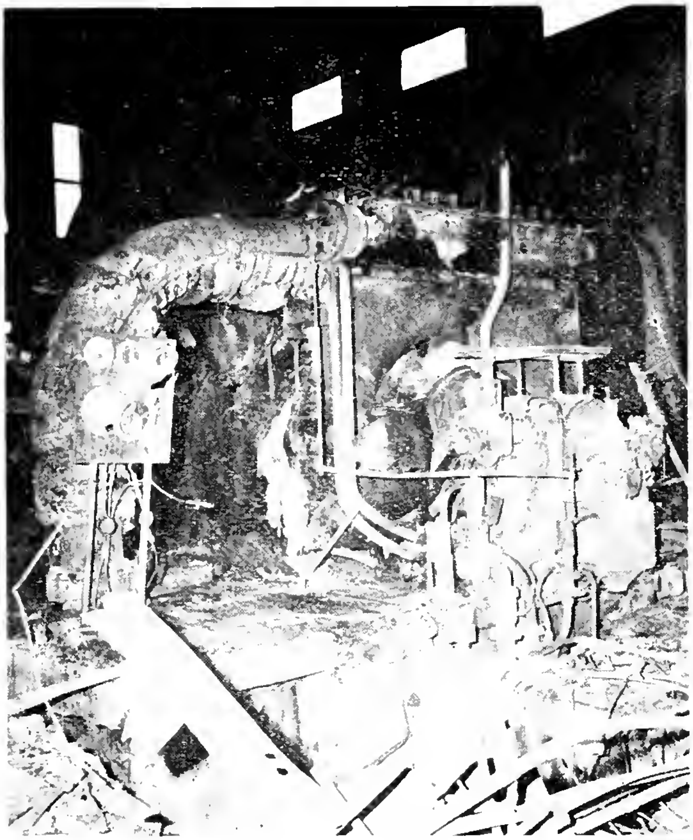


Photo 5—View showing bomb hit to left of turbine end of unit No. 3

Photo 6—View showing bomb hit in space between turbogenerator bay and transformer house

PLANT REPORT NUMBER 10

SENJU STEAM POWER PLANT

TOKYO, JAPAN

DATE INSPECTED 18 OCTOBER 1945

Summary.

1. The Senju Steam Power Plant, located on the left bank of the Ara River in the northern edge of Tokyo, has a name plate capacity of 77,500 KW. The main plant is located in a single, large, concrete building with adjacent coal storage and handling equipment. There are 4 steel stacks approximately 275 ft in height that made the plant easily identifiable. Its yearly output averaged 71 million KWH during the 3 war years, and, while not the largest plant, it was a very important one in the Tokyo area, especially during the dry season when hydro power was insufficient. In addition, the generators were arranged for operation as synchronous condensers for use during the season when hydro power was available.

2. This plant was never a primary target nor was it ever damaged from any cause during the war.

3. No physical damage occurred; therefore, there was no production loss, nor could any measure of recuperability be obtained. However, this plant was as vulnerable as any other steam power plant and particularly so because of its accessibility and ease of identification.

4. The size, importance, and location had been correctly evaluated in intelligence data.

5. The lack of even reasonable maintenance was very apparent and is indicative of the poor operation generally seen throughout all of the Japanese steam power plants.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

The Senju Steam Power Plant ranked 15th in size in all Japan and 6th in the Tokyo supply area. It was primarily used as base load during the dry hydro season; however, load charts show that it operated to a considerable extent throughout the entire year. During the period of abundant hydro power, the generators were used as synchronous condensers for power factor correction and stabilizers on the long transmission lines, which was an important factor in the full utilization of transmitted power from hydro sources. The plant averaged 71 million KWH per year during the 3 war years and its output in KWH was as follows:

	1942	[illegible]	1944	1945
Jan.	11,408,000	24,149,000	16,299,000	1,755,000
Feb	7,441,000	13,465,000	19,389,000	5,117,000
Mar	37,000	15,660,000	16,581,000	335,000
Apr.	7,719,000	395,000	3,032,000	0
May	3,914,000	0	0	0
June	6,046,200	2,086,000	0	0
July	10,758,800	3,334,000	434,000	0
Aug	8,214,200	3,449,000	0	0
Sept	5,513,800	2,528,000	748,000	------------
Oct	3,932,200	0	427,000	------------
Nov.	6,660,000	1,010,000	0	------------
Dec	14,648,000	6,747,000	0	------------
Total	86,292,200	72,823,000	56,910,000	7,207,000

It is interesting to note the decline of production commencing in April 1944 and also the complete absence of any production after March of 1945 which clearly indicates the loss of demand through the damage to, or dispersion of, industry. The plant output was supplied to the transmission lines of the Japan Electric Generation and Transmission Company for distribution with the majority of the output utilized in the Tokyo district.

2. Physical description of plant.

a. The plant is located on a 12 acre rectangular plot on the left bank of the Ara River in the northern edge of the city of Tokyo. The main plant is housed in one large, steel-frame, reinforced concrete building with the generator hall the equivalent of 5 stories in height and running the entire length of the building. The boiler room is in 2 sections, each section being perpendicular to the generator hall and attached to opposite ends of the same side. Each of these sections has 2 steel stacks, making a total of 4 stacks. These stacks are approximately 275 ft in height and are very prominent. Parallel to the generator hall and a part thereof, but only about 3 stories in height, is the electrical bay containing all electrical controls, bussing, switching equipment, and transformers. (Exhibit A) The boiler rooms contain a total of 12 B&W Marine type, stoker-fed boilers, supplying steam at 225 lbs. psi, 600 degrees Fahrenheit. There are 4 turbogenerator units with total of 77,500 KW in generator name plate capacity. One is a Seiman Schukert 2500-KW, 3000-RPM, and 3 are Westinghouse 25,000-KW, 1500-RPM, and all generate 11,000-volt, 3-phase, 50-cycle current. The three 25,000-KW generators can be uncoupled from the turbines and are arranged to be used as synchronous condensers,

being brought up to speed electrically by means of a Westinghouse motor generator set. This set has a 2500-HP motor, 7500-KVA, 3-phase, 1,1000-volt, 600-RPM generator, the generator of which also serves as a synchronous condenser. The electrical bay contains nine 8500-KVA, single-phase, OIWC transformers in 3 banks of 3 transformers with generators connected direct to each bank. Generator voltage is stepped up to 66 KV for transmittal by high voltage lines to the Hanabata substation.

b. Coal is normally delivered by ship or barge direct to the dock on the Ara River. Unloading is accomplished by a system of belt conveyors, and there is a large storage area between the docks and the plant. Distribution in the storage area is by traveling cranes, and coal is transported to bunkers above the boilers by belt conveyors. The source of fuel is either Hokkaido or Kyushu and it has a Btu value of about 11,000. There was never a lack of coal during the war, but quality was very poor and the reserve storage dangerously small.

3. The plant is owned by the Japan Electric Generation and Transmission Co.

Attacks.

None.

Effects of Bombing.

1. Physical damage.

This plant was never a primary target nor was it damaged at any time from bombing or other causes. There was practically no effort made to provide any protective installations.

2. Production loss.

a. The production of this plant averaged approximately 71 million KWH during the 3 war years; however, production declined during the latter part of the war with none since March 1945. This was due to loss of load due to bombing of industry or areas plus some loss because of industry dispersion. Therefore, planned production was an undetermined factor and the economic aspect, had this plant been bombed, cannot be accurately determined.

b. No substitution or modification possible.

c. Causes for loss of production.

(1) None from physical damage.

(2) None from diversion.

(3) None from protective measures.

(4) None from absenteeism or inefficiency.

(5) Some production was lost because of the poor grade of coal received since their normal quality coal could not be obtained because of shipping losses.

3. Recuperability cycle.

Since there was no damage, this was not a factor.

4. Vulnerability.

This plant, as are all steam plants, was vulnerable, and this is fully covered in the final industry report. In particular, this plant was easily identified due to the prominence of its tall stacks.

Intelligence Check.

1. *a.* OSS report correctly located and described this plant though the capacity given as well as some of the equipment listed was erroneous.

b. The Air Objective Folder 90.17 for Tokyo area issued by the Office of Chief of Air Staff, Intelligence, listed this plant as Target 230, correctly located it on maps, and evaluated its importance fairly well, though it failed to indicate the full use of the plant in its function of providing synchronous condensers.

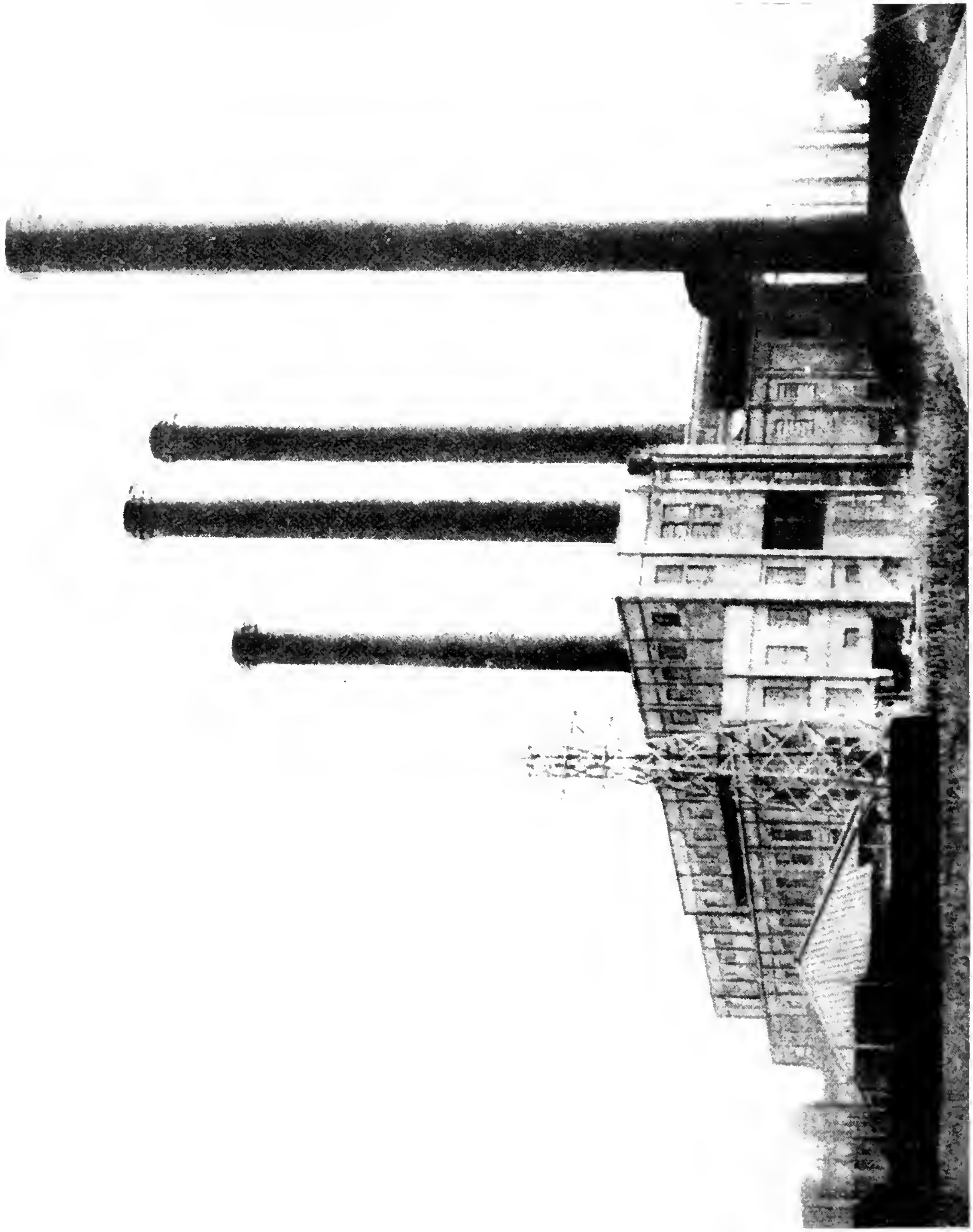
c. JTG information was similar in extent.

Data Relevant To Other Studies.

Only a very small quantity of very poor quality coal was on hand because of the curtailment of transportation.

Evaluations and Impressions.

The plant showed unmistakable signs of neglect in maintenance, and since it had been operated throughout the war, this is indicative of the general inability or lack of initiative on the part of the Japanese in all their operations.



PLANT REPORT NUMBER 11

TSURUMI STEAM POWER PLANT

KAWASAKI (NEAR TOKYO) JAPAN

DATE INSPECTED 18 OCTOBER 1945

Summary.

1. The Tsurumi Steam Power Plant, located on Tokyo Bay near Kawasaki, has 178,500 KW in name plate generating capacity. It is in 2 large, concrete buildings with coal storage and handling equipment on one side and an outdoor transformer and switching station on the other. Its yearly output averaged approximately 158 million KWH annually during the 3 war years. It was the third in size in Japan, first in the Tokyo area, and an important plant in the highly industrialized area of Tokyo, especially during the dry winter season when hydro power was scarce.

2. This plant was never a primary target, but was damaged in three raids on adjacent targets, by the Twentieth AF. On 12/13 July 1945, 452 tons were dropped in the entire raid, and 23 bombs fell within the effective area of this plant. On 25/26 July 1945, 650 tons were dropped in the entire raid, and 22 bombs fell within the effective area of this plant. On 1/2 August 1945, 1017 tons were dropped in the entire raid, and 12 bombs fell within this plant area.

3. The principal physical damage was the complete destruction of the control room, almost complete destruction of the main transformer bank, and sufficient destruction of the coal handling equipment to render it useless. The plant was not in operation at the time of the damage, but at least one year's production loss was caused. No attempt at recuperation has been made. The vulnerability of power plants is fully shown since the destruction of a portion rendered the entire plant inoperative.

4. The size, importance, and location had been correctly evaluated in intelligence data, but damage had not been correctly stated in damage assessment reports.

5. Significant at this plant is the apparent ease with which a steam power plant can be rendered inoperative by a small tonnage of bombs per acre.

The Plant and Its Function In Enemy Economy.

1. The Tsurumi plant was one of the most important steam plants in Japan, ranking third in size in all Japan and first in size in the Tokyo supply area. While it was used principally during the dry winter season from November through March, it also supplemented hydro power at other times of the year. Complete production figures for the war years are given in Exhibit B. Totals for these years were as follows:

	KWH
1942	209,102,520
1943	146,268,840
1944	119,181,040
*1945	47,392,560

*First 3 months only—no production since March 1945.

The product was supplied to the transmission network for general distribution with the major portion being utilized in the Tokyo area, both for base and peak loads, with base loads being of particular importance during the dry season.

2. *a.* The plant is located on Tokyo Bay. It was built on reclaimed land about 4 miles southwest of the mouth of the Tama River. The plant area is an irregular rectangle approximately 970 ft by 1070 ft with a total acreage of approximately 24 acres. (Exhibit A) It is in 2 parts, the older part being in a reinforced concrete building approximately 160 ft by 200 ft, and the new part in an adjoining, concrete building approximately 210 by 240 ft. (Exhibit C, photo No 1) Each building contains a complete plant, including a generator hall and boiler house section, but there is a common electrical control room located in the new building and an adjacent, outdoor, common, switch, and transformer station. There is a total of 6 stacks, but they are not tall or particularly visible. The plant area is adjacent to a 600-ft canal, and between the main buildings and this canal is a large coal storage and handling yard which is readily identifiable. Also in the same immediate vicinity are a large flour mill and an oil tank farm, and directly across the canal is the Kawasaki Power Plant. The entire area is highly industrialized. The older part was completed in 1926. The boiler room contains 6 B&W, water tube type boilers, 4 of which are 70-T/hr, and 2 are 90-T/hr. The generator room has 2 GE Curtis, impulse-type, horizontal shaft turbines, each with a GE 35,000-KW generator. In addition, there is a 2500-KW, GE, house generator operated by a separate turbine. The new part was completed in 1935. The boiler room contains 4 CTM boilers each 170-T/hr. The generator hall contains 1 Mitsubishi

and 1 AEG, tandem, compound, impulse-type, horizontal shaft turbine, each with a 50,000-KW generator of the same make, and on the same shaft of each is a 3,000-KW house generator. The total name plate capacity of the plant is 170,000 KW in main generators and 8,500 KW in house generators.

b. The plant normally used coal of approximately 6400 cal kg (11520 Btu) that was shipped by barge or rail from NE Japan. The quality of the coal became progressively poorer, and the maximum output possible was less than 100,000 KW. There were no power shutdowns due to lack of fuel.

3. The plant is owned by the Japan Electric Generation and Transmission Company. Information was obtained from Mr. Kadata, ch engr for the plant.

4. The plant normally uses approximately 300 employees but recently the total has been reduced to between 150 and 160. They operate 2 shifts. Operation of the plant is normally seasonal, but nonoperating periods are devoted to maintenance.

Attacks.

There were no specific attacks on this plant; however, it was damaged during 3 raids directed against adjacent targets. The first damage was on 12/13 July 1945 during a night attack on the Kawasaki Petroleum Center, mission No. 267 of the Twentieth AF. Fifty-three A/C of the 315th Wing dropped 452 tons of 500-lb GP bombs, fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 16,000 feet with 8/10—10/10 weather. In this raid, 23 bombs fell within this plant area, but none hit the buildings. The second damage occurred on 25/26 July 1945 during a night attack on the Petroleum Center and Mitsubishi Oil Refinery at Kawasaki, Mission No. 291 of the Twentieth AF. Seventy-five A/C of the 315th Wing dropped 650 tons of 500-lb GP bombs fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 17,000 ft with weather from 0/10—10/10. In this raid, 22 bombs fell within this plant area of which 2 fell on the buildings. The third damage was on 1/2 August 1945 during a night attack on the Kawasaki Petroleum Center at Hayama and Mitsubishi Oil Refinery, Mission No 310 of the Twentieth AF. One hundred and Twentieth A/C of the 315th Wing dropped 1017 tons of 500-lb GP bombs fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 17,500 ft with 8/10—10/10 weather. In this raid, 12 bombs fell within this plant area of which 1 fell on buildings.

Effects of Bombing.

1. Physical damage.

a. (1) The damage on 12/13 July 1945 was as follows:

One bomb hit directly on a 15,000-KVA, 11/66-KV, single-phase transformer, completely destroying the transformer and setting fire to the oil which destroyed 2 adjacent transformers. Much miscellaneous damage was done to adjacent transformers, bussing, and cables. (Exhibit C, photos 4 and 5)

One bomb hit a water filter doing minor damage.

Sixteen bombs hit coal conveyors and coal storage, seriously damaging and rendering the coal conveyor completely inoperative. (Exhibit C, photos 2 and 3)

Three bombs hit the cooling water intake tunnel, causing serious damage.

One bomb badly damaged a wooden warehouse.

One bomb did minor damage to a wooden building.

(2) The damage on 25/26 July 1945 was as follows:

Two bombs completely wrecked the coal drier. (Exhibit C, photos 6 and 7)

One bomb hit the corner of a new generator hall, exploded in a section used as a warehouse and set fire to inflammable contents. The fire completely destroyed the control room. (Exhibit C, photo 8)

One bomb hit on the new generator hall, damaging the crane rail and doing minor fragmentation damage to a 50,000-KW generator and instruments. (Exhibit C, photo 9)

Three near misses on the generator hall damaged the condenser water lines.

One bomb hit in the center of the switch yard completely destroying a 22-KV, 600A, oil, circuit breaker and doing much damage to the station structure, insulators, busses, etc. (Exhibit C, photo 10)

One bomb hit on the ash handling equipment doing serious damage.

Two bombs did further damage to the coal conveyor.

One bomb damaged a section of the cooling water intake line.

The balance of the bombs did minor damage throughout the area.

(3) The damage on 1/2 August 1945 was as follows:

One bomb hit on the edge of a new boiler house, penetrating through the roof and detonating close to the ceiling near a boiler, seriously damaging the economizer. (Exhibit C, photo 13)

Two hits on the oil drums near a corner of the new house demolished the drums. (Exhibit C, photo 12)

One hit the blow-off tank near a corner of the new boiler, demolishing the tank completely. (Exhibit C, photo 11)

Two hits on the coal transporting equipment completely demolished one section.

The balance of the bombs did minor damage throughout the area.

Only a minor amount of protective measures had been taken. The main buildings had been painted with an irregular pattern of black and white paint as camouflage. (Exhibit C, photos 1 and 7) The generators and turbines had been enclosed in a ring of dirt-filled straw bags. (Exhibit C, photo 14) Across the center of each generator hall had been placed a protective wall, about 8 ft high by 35 ft long, built of 2 sides of steel plates on angle iron frames placed about 12 in apart with the center filled with sand. (Exhibit C, photo 9) Concrete vaults for protection of workmen had been placed at various points throughout the plant. (Exhibit C, photo 8) Concrete, blast, protective walls were built around the large transformers in the open air transformer and switching station. (Exhibit C, photos 4 and 5)

b. From information supplied by local officials and by personal inspection, a bomb plot has been prepared. (Exhibit B).

2. Production loss.

a. This plant produced approximately 209 million KWH in 1942 which had declined to 146 million in 1943, to 119 million in 1944, and went down to 47 million in 1945. This variation was due in part to seasonal demands dependent on the supply of hydro power, and in part to the poor quality and limited quantity of coal available, especially during the latter part of the war. The plant was not operating at the time of the various bomb damage dates as this power was not needed, since hydro was available, and power demands were down because of the loss of industrial load due to bombing and/or industrial plant dispersal. No assessment can therefore be made as to the loss of production caused by the bombing of this plant. However, it is reasonable to assume that the loss of production because of bomb damage would have been at least one season's normal production of possibly 158 million KWH, had conditions required the power.

b. No substitution or modification was possible.

c. Causes for loss:

(1) The complete plant was rendered inoperative because of the destruction of the coal handling equipment and the control board, and partly inoperative by destruction of the main transformer banks.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused by protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) A loss of production was caused throughout the war because of the poor grade of coal used due to the lack of transportation for the better coal.

3. Recuperability cycle.

a. No repairs had been made or were started. Based on the ability to secure required materials and skilled labor, it is estimated that complete repairs could have been made and the plant put back in operation as follows:

(1) From damage of 13/14 July 1945, repairs would require approximately 6 months.

(2) From damage of 25/26 July 1945, repairs would require approximately 12 months.

(3) From damage of 1/2 August 1945, repairs would require 6 months.

b. No production had been reattained at time of inspection.

c. No portion of the plant could have been utilized because of the destruction of portions essential to the entire plant.

4. Vulnerability.

The vulnerability of all steam power plants is fully covered in the final report which is applicable to this plant.

Intelligence Check.

1. *a.* OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder No 90.17 for Tokyo Area, issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as Target 110, correctly located it on maps, evaluated its importance, and gave a reasonably correct plot plan; however, photographic information was obsolete.

c. JTG information was essentially correct. Aerial photographic cover was excellent and location of buildings correct in all except one minor point. Size of the plant area given was slightly in error, and weapon recommendation was not concurred in.

2. Records of the raids in which this plant was damaged are covered in reports on raids 267, 291, and 310, on Targets 116, 127, and 128.

a. Damage Assessment Report No 157, covering the raid of 12/13 July 1945 does not list any damage to this plant, although aerial photographs clearly show a number of strikes and damage.

b. Damage Assessment Report No 173, covering raids of 25/26 July 1945 and 1/2 August does not list any damage, although aerial photographs clearly show a number of strikes and damage.

c. Damage Assessment Report No 184, covering

raid of 1/2 August 1945 lists additional assessment of damage and includes this power plant with only minor damage, although damage was severe.

3. No mention was made in any damage assessments of recuperation or dispersal other than to mention in Report No 184 that the plant was inoperative, which was correct.

Data Relevant To Other Studies.

The shortage of coal and the necessity of using poor grade coal was due to transportation difficulties, especially the curtailment of barge transportation.

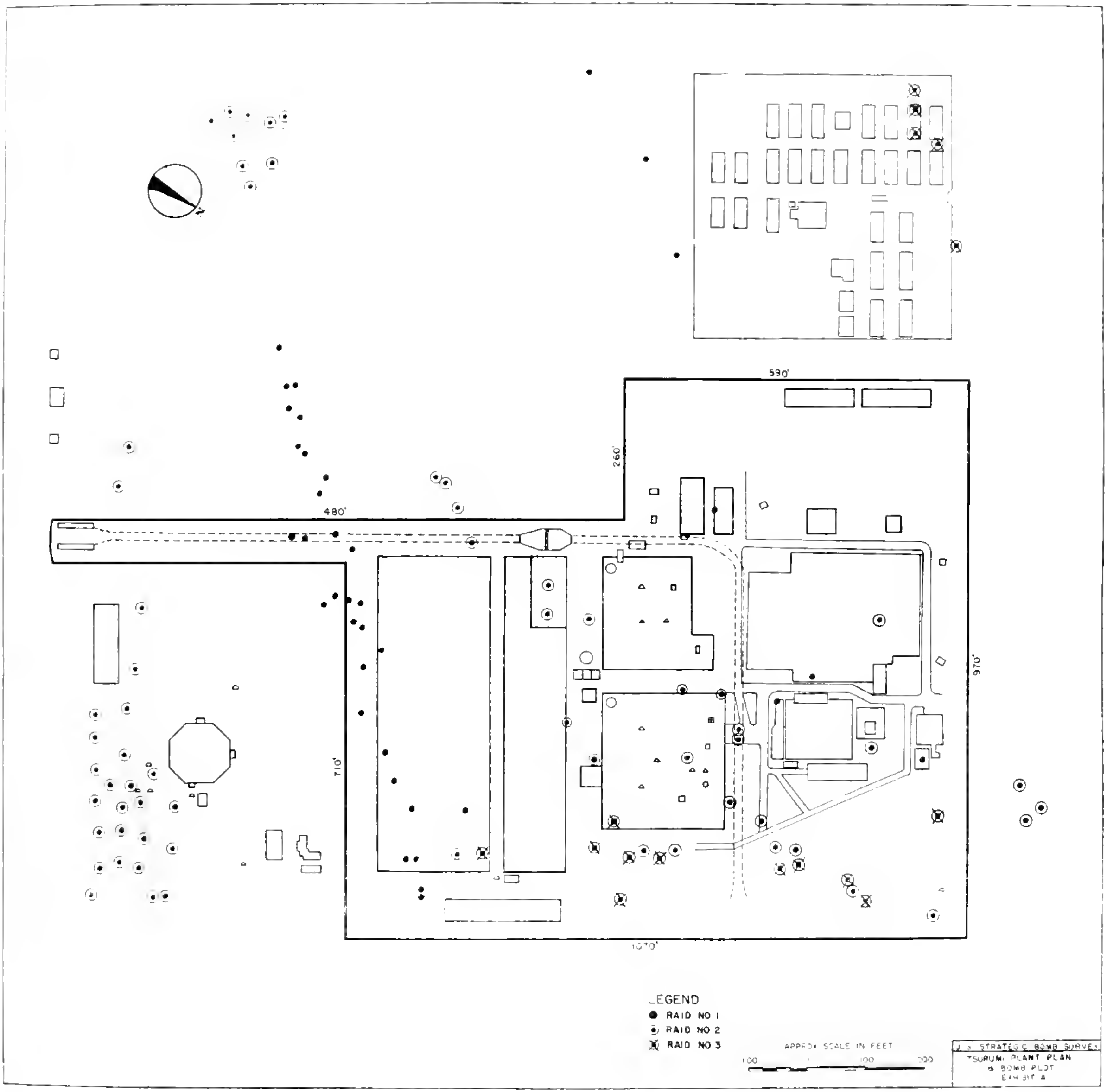
Evaluations and Impressions.

This plant is a typical example of generally poor Japanese steam generating plant operations. The general appearance of the plant indicates that the maintenance was bad. No effort to clean up any of the bomb damage had been made. The use of a single control room for both sections of the plant proved unwise as its destruction rendered the entire plant inoperative.

Exhibit B

Tsurumi Power Plant Production in KWH

	1942	1943	1944	1945
Jan	34, 741, 120	48, 175, 870	36, 522, 760	19, 752, 400
Feb	35, 387, 120	12, 696, 600	33, 179, 360	26, 425, 640
Mar	1, 478, 440	30, 184, 810	28, 985, 960	1, 214, 520
Apr	0	3, 246, 680	3, 164, 400	0
May	1, 063, 680	1, 848, 960	0	0
June	10, 829, 480	116, 800	425, 400	0
July	13, 872, 560	5, 392, 320	2, 010, 880	0
Aug	33, 089, 760	11, 597, 680	2, 400	0
Sept	9, 307, 840	6, 369, 880	8, 669, 880	0
Oct	7, 201, 600	0	4, 830, 600	
Nov	22, 417, 120	7, 808, 800	0	
Dec	39, 718, 800	18, 830, 440	1, 389, 400	
Total	209, 107, 520	146, 268, 840	119, 181, 040	47, 392, 560



590'
260'
480'
970'
710'
1070'
LEGEND
RAID NO 1
RAID NO 2
RAID NO 3
APPROX SCALE IN FEET
100
100
200
U. S. STRATEGIC BOMB SURVEY
TSURUMI PLANT PLAN
& BOMB PLOT
EXHIBIT A

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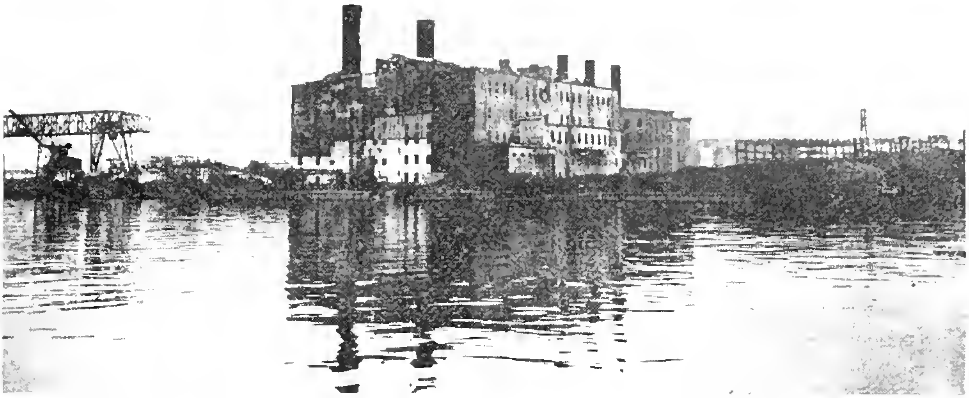

Photo 1—General view of east side of plant from across canal

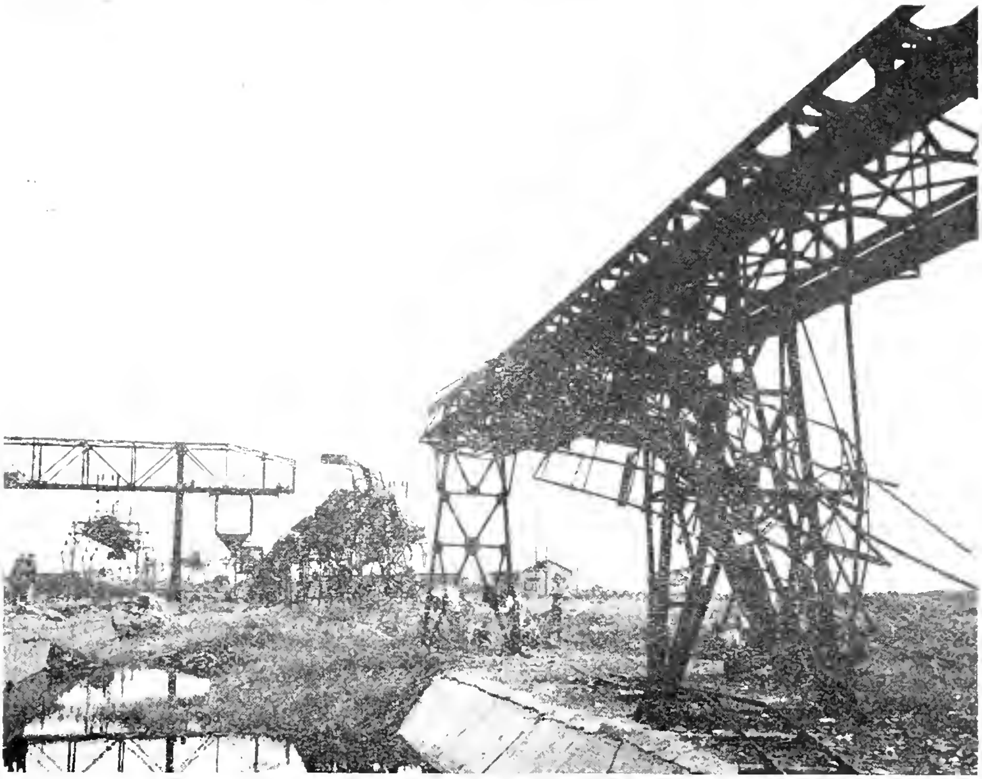

Photo 2—Damaged coal conveyors—Raid number 1

Photo 3—Damaged coal conveyors and crane

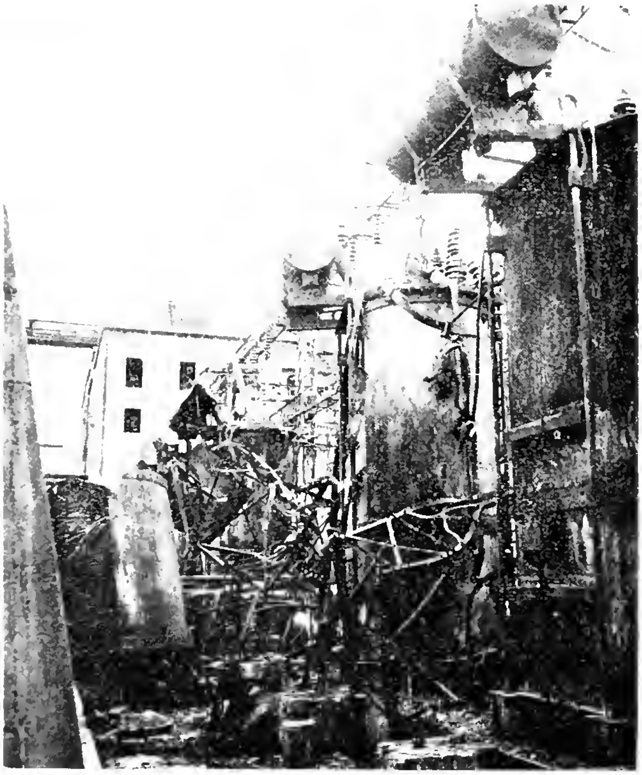

Photo 4—Main transformer bank showing transformer ruined by direct hit and adjoining ones ruined by oil fire—Raid number 1

Photo 5—Rear view main transformer bank note protective wall Raid number 1

Photo 6—Damaged coal driers blown completely off foundation Raid number 2

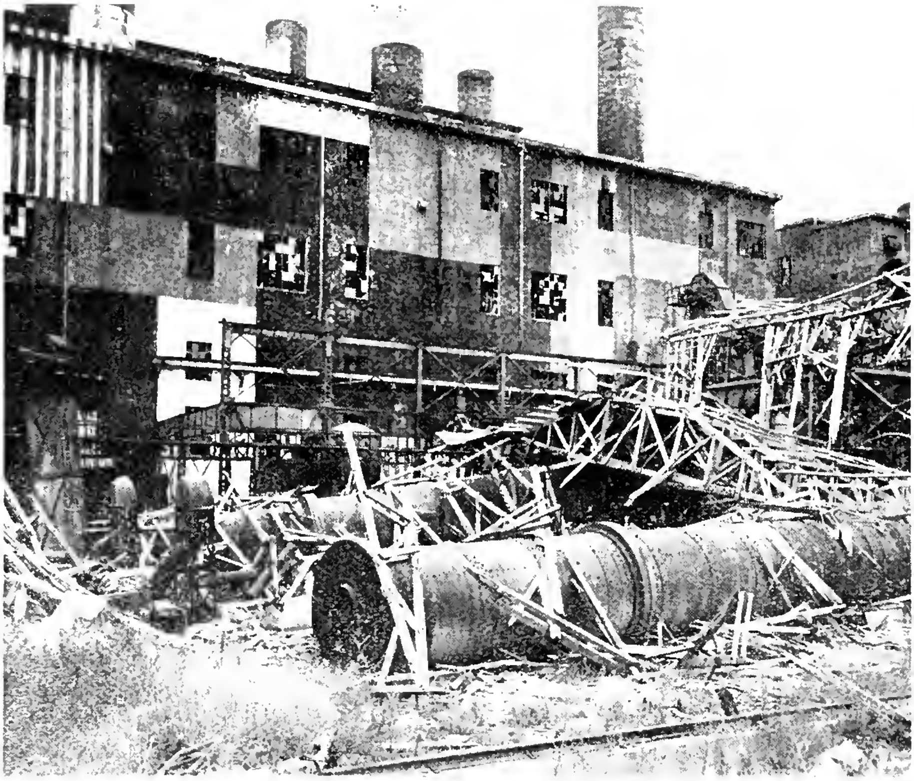

Photo 7—Damaged coal driers and general debris. Note camouflage paint on building. Raid number 2

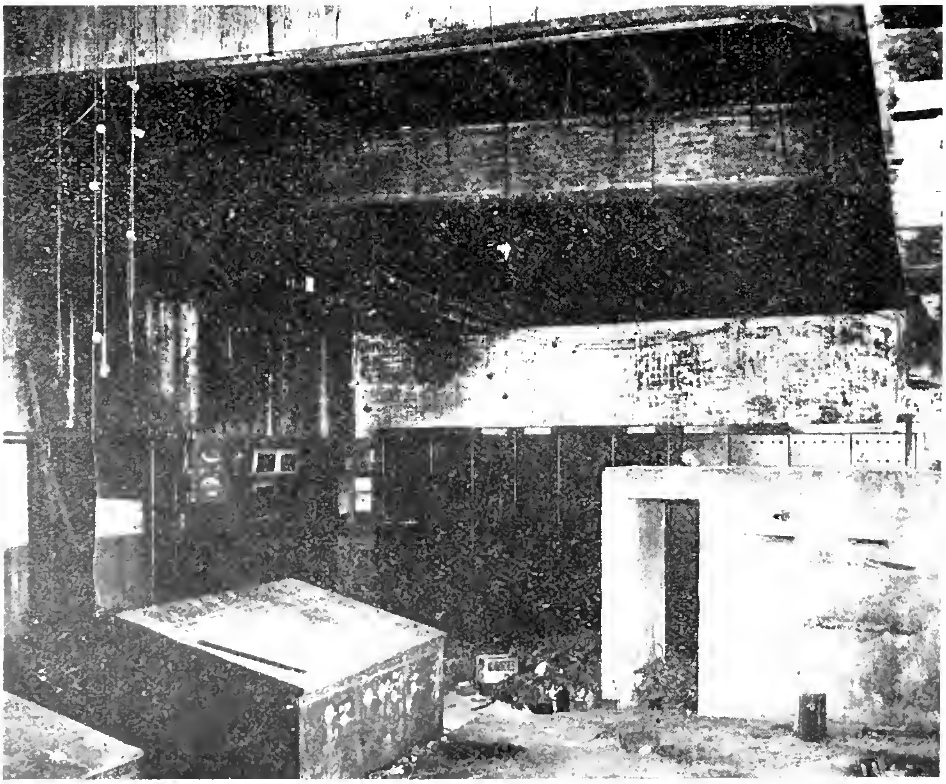

Photo 8—Burned out control room. Note bomb shelter for operators. Raid number 2

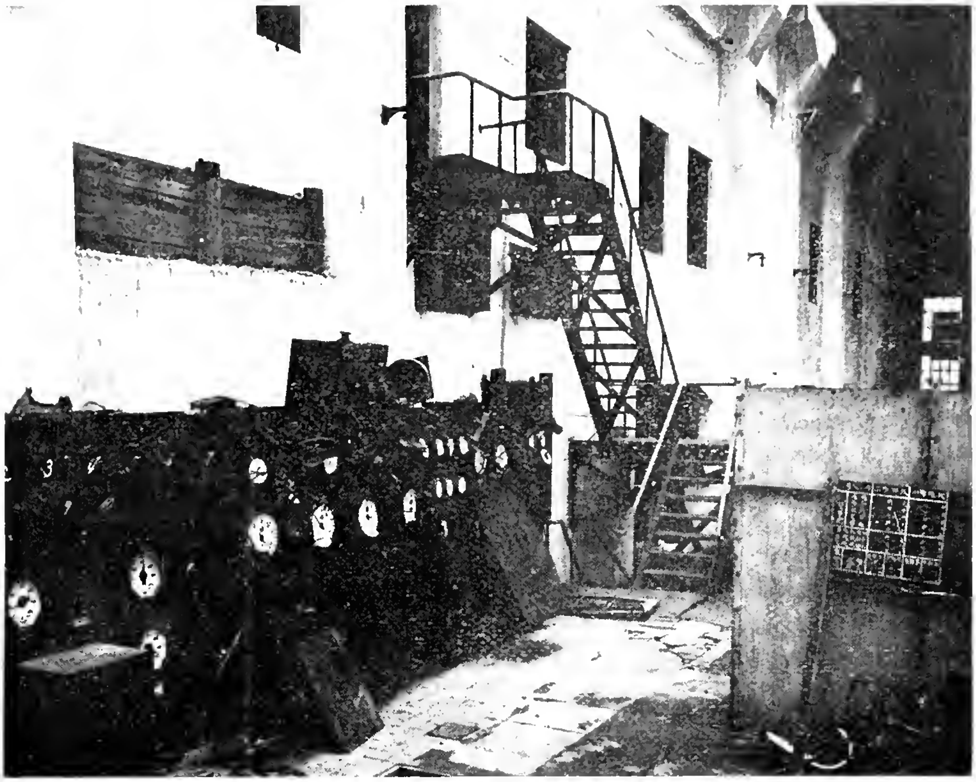

Photo 9—Damaged turbine control instrument board in generator hall—Note blast protective barrier wall—Raid number 2

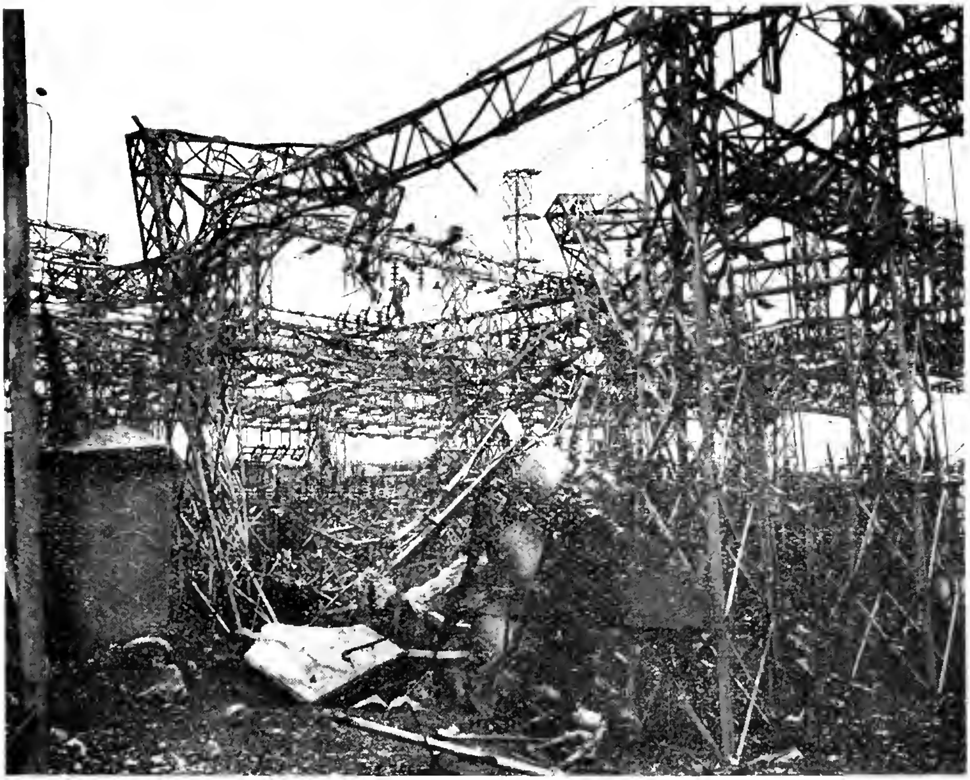

Photo 10—Destroyed O.C.B. and other damage to switch yard—Raid number 2

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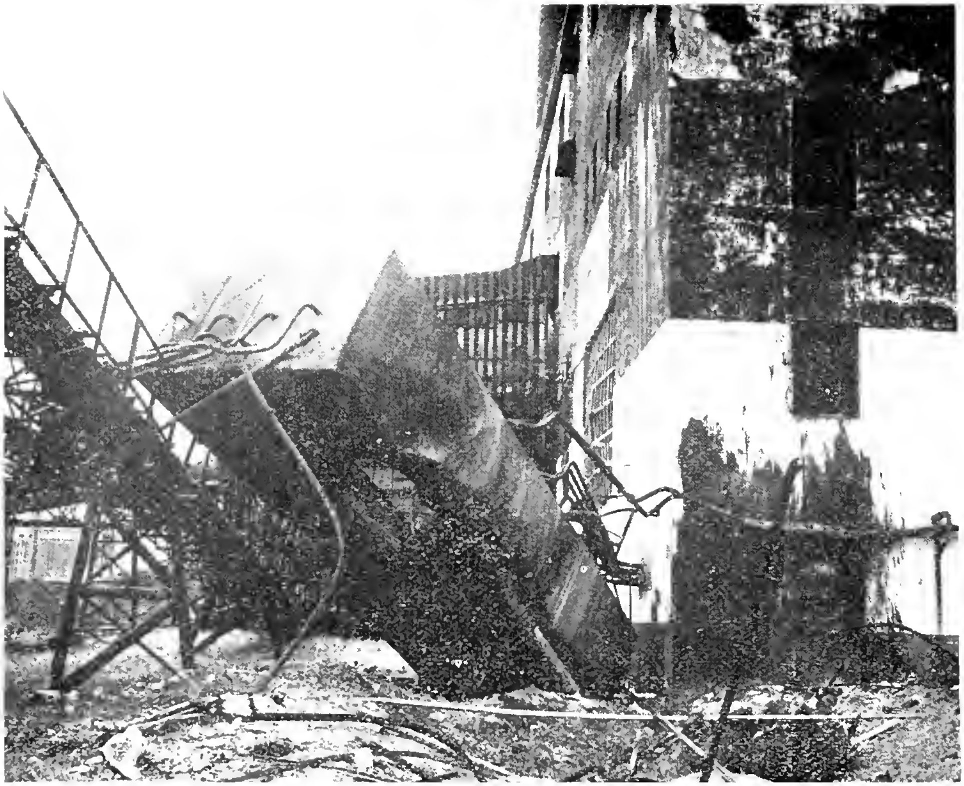


Photo 11—Damaged blow down tank - Raid number 3

Photo 12—Damaged oil container blown completely out of ground—Raid number 3

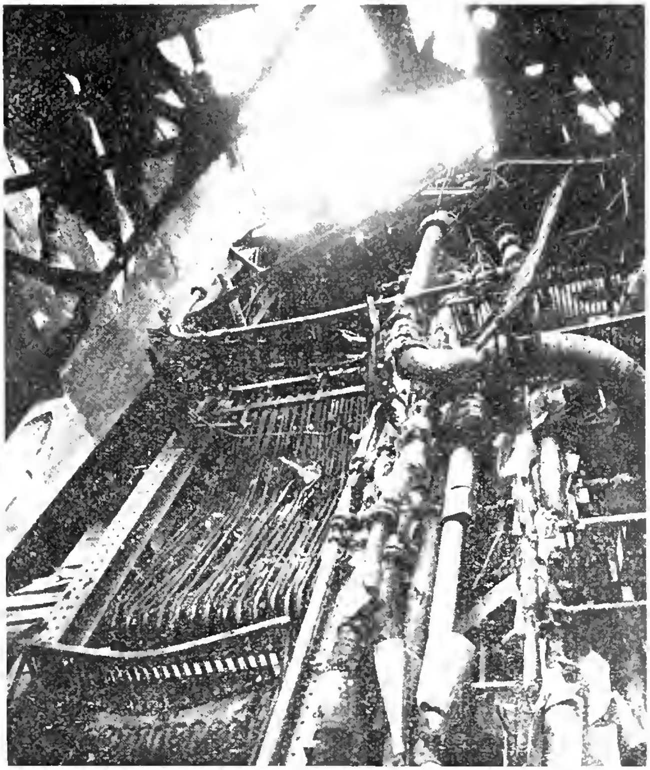


Photo 13—Damaged economizer by direct hit on boiler house—Raid number 3

Photo 14—Method of blast protection around turbogenerators

PLANT REPORT NUMBER 12

USHIODA STEAM POWER PLANT

KAWASAKI (NEAR TOKYO) JAPAN

DATE INSPECTED 18 OCTOBER 1945

Summary.

1. Ushioda Steam Power Plant, located on the Kawasaki water front in Tokyo Bay, has 77,000 KW in name plate generating capacity. It is in a large, steel, reinforced concrete building with an indoor transformer and switching station and an outdoor coal storage and handling equipment. Its yearly output averaged approximately 91 million KWH during the 3 war years. It was an important steam station in the highly industrialized Tokyo area and, while its output was mainly during the dry season when hydro was insufficient, it operated to some extent throughout the entire year.

2. This plant was never a primary target but was damaged in 3 raids on adjacent targets by the Twentieth AF. On 12-13 July 1945, 452 tons were dropped in the entire raid, and 28 bombs fell within the effective area of this plant. On 25/26 July 1945, 650 tons were dropped in the entire raid, and 14 bombs fell within the effective area of this plant. On 1/2 August 1945, 1,017 tons were dropped in the entire raid, and 26 bombs fell within this plant area.

3. The principal physical damage was the destruction of the buss bar feeders, demolishing of portions of the inlet and outlet canal of the circulating water system, destruction of the coal handling and drying equipment, and damage to one turbogenerator. The plant was not in operation at the time of the damage, but at least 9 months' production loss was caused, which at the average rate of production would amount to approximately 67 million KWH. No attempt at recuperation has been made. The vulnerability of steam power plants is shown by the fact that the destruction of a portion rendered the entire plant inoperative.

4. The size, importance, and location had been correctly evaluated in intelligence data, but no damages had been reported in damage assessment reports.

5. Significant in this plant are the apparent ease with which steam power plants can be rendered inoperative, and the small tonnage per acre required to do it.

The Plant and Its Function In Enemy Economy.

1. The Ushioda plant is the third largest steam plant in the Tokyo supply area. While it is principally used during the dry winter season from November through March, it also supplemented hydro power at other times of the year. Complete production figures for the war years are given in Exhibit B. Totals for these years are as follows:

	KWH
1942	108,203,800
1943	100,366,800
1944	64,407,600
*1945	22,618,000

*The plant has been out of operation since March 1945.

The entire power output of this plant is fed to a common transmission system with the majority of power utilized in the Tokyo and Yokohama area, both for base and peak loads with base loads of particular importance during the dry season.

2. *a*. The plant is located on the Kawasaki water front in Tokyo Bay, built on reclaimed land about 4 miles southwest of the mouth of the Tama River. The plant area is a rectangular compound approximately 720 ft by 753 ft with a total acreage of approximately 12.8 acres. The plot plan of the area is shown in Exhibit A. The main plant is in a 5-story building about 190 ft sq, of steel and concrete construction, with a concrete roof, and sidewalls of corrugated sheets made of asbestos and cement composition. It has 2 stacks about 110 ft high made of heavy sheet iron. The building and stacks are camouflaged with white and black paint. Approximately ½ of the entire plant area is used for coal storage and handling equipment.

The plant was completed in 1931 and has a total name plate capacity of 77,000 KW. The boiler room has 3 B&W water tube boilers carrying a steam pressure of 375 lbs psi. There is room for the installation of a 4th boiler. The boilers have a capacity of 130-T/hr and were designed for use of 12,000 Btu coal. There are 2 Rateau, multi-stage, impulse, tandem, compound turbines and 2 35,000-KW Metropolitan Vickers generators. In addition, there is a separate 7,000-KW house turbogenerator. The switching and transformer station is the indoor type and is located as an integral part of the main building. It contains two 3-phase, 43,750-KVA, oil-immersed, air-cooled, 11/66-KV transformers. The entire plant is in a run down condition, especially the boiler house.

b. The plant normally used coal from Manchuria transported by ship. During the war, water shipments were unobtainable. Some Kyushu coal was obtained by rail but for the most part coal from Honshu was used. This coal was of poor quality and, therefore, the maximum output obtainable was only 42,000 KW. The plant was never out of fuel as it was given 1st priority on coal supply.

3. The plant is owned by the Japan Electric Generation and Transmission Co. Information was obtained from Mr. S. Nakamura, asst chief operator of the station and Mr. Murota, head of the Electrical Engineering Department of the Tokyo Branch of the Japan Electric Generation and Transmission Co.

4. The plant normally uses a total of 150 employees operating in 2 shifts. This has been reduced to 50 at present.

Attacks.

There were no specific attacks on this plant; however, it was severely damaged during 3 raids directed against adjacent targets.

The first damage was on 12/13 July 1945 during a night attack on Kawasaki Petroleum Center, mission No. 267 of the Twentieth AF. Fifty-Third A/C of the 315th Wing dropped 452 tons of 500-lb GP bombs, fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 16,000 ft with 8/10—10/10 weather. In this raid 28 bombs fell within this plant area, none of which hit any main buildings.

The second damage occurred on 25/26 July 1945 during a night attack on the Petroleum Center and Mitsubishi Oil Refinery at Kawasaki, mission No 291 of the Twentieth AF. Seventy-Fifth A/C of the 315th Wing dropped 650 tons of 500-lb GP bombs, fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 17,000 ft with weather from 0/10—10/10. In this raid 14 bombs fell within the plant area, none of which hit any main buildings.

The third damage was on 1/2 August 1945 during a night attack on the Kawasaki Petroleum Center at Hayama and Mitsubishi Oil Refinery, mission No 310 of the Twentieth AF. One-Hundred and Twentieth A/C of the 315th Wing dropped 1,017 tons of 500-lb GP bombs, fused 1/10 sec nose and 1/40 sec tail, from a height of approximately 17,500 ft with 8/10—10/10 weather. In this raid 26 bombs fell within the plant area, and 2 hit the main building.

Effects of Bombing.

1. Physical damage.

a. (1) Damage on 12/13 July 1945 was as follows:

Three bombs were very effective. The circulating, water, discharge tunnel was demolished by a direct hit. The main warehouse was completely destroyed by a direct hit. Ten men who sought shelter in a ditch were killed. Two near hits made the bridge crane for coal distribution useless by damaging the railway of the main track.

(2) Damage on 25/26 July 1945 was as follows:

The circulating, water, inlet, canal tunnel was demolished by 3 direct hits. The blast effect of one of these hits heavily damaged the coal dryer equipment by puncturing the dryer drum and dislocating the main anchor that supported the dryer drum, due to the collapse of the tunnel itself (Exhibit B, photo 11). The inclined belt conveyor of the coal handling equipment was rendered useless by one direct hit, and one near miss damaged the long coal conveyor located on the canal side.

(3) The damage on 1/2 August 1945 was as follows:

Nineteen bombs were very effective. The most serious damage was done by a direct hit on the station building, cutting the main control cables and doing heavy damage to the 66, 11, and 3.3-KV busses (Exhibit B, photos 1 and 2). The blast caused no fire, but the fragmentation did considerable damage to the interior of the plant, particularly in the turbine and generator hall (Exhibit B, photo 6). One turbine was considerably damaged, and there was a hole in the generator housing (Exhibit B, photos 3, 4, and 5). The main cable of the 100-ton crane was damaged and the crane rendered useless (Exhibit B, photo 8). The control board of the auxiliary equipment on the generator floor was damaged. External damage was done by 3 near hits at the west corner of the building (Exhibit B, photo 10). Nine double houses of plant employees were destroyed by 5 hits. The rail of the already damaged bridge crane was further damaged by 2 more hits. A small warehouse was destroyed. One 2-circuit, transmission tower and one 4-circuit tower were demolished. One direct hit demolished the ash handling equipment.

Only a minor amount of protective measures had been taken. Barriers of fabricated steel, made of angle iron placed approximately 4 in apart and filled with timbers, were placed between the machines. This wall proved very effective as there was no apparent damage to one turbogenerator which was located well within the radius of the blast effect.

b. From information supplied by local officials and by personal inspection, a bomb plot has been prepared. (Exhibit A)

2. Production loss.

a. Since the plant was not in operation at the time the damage occurred, there was no actual production

loss. However, based on an estimate of at least 9 months to repair damage and place in operating condition, about 67 million KWH were lost of an average year's production.

b. No substitution or modification was possible.

c. Causes for loss:

(1) The complete plant was rendered inoperative, especially due to the destruction of the coal handling equipment, damage to the control cable and bus bars, damage to one turbogenerator, and damage to the control board of the auxiliary equipment on the generator floor.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused by protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) A loss of production was caused throughout the war because of the poor grade of coal used due to the lack of transportation for better coal.

3. Recuperability cycle.

a. No repairs had been made or even started. Based on the ability to secure required materials and skilled labor, it is estimated that complete repairs could have been made and the plant put back in operation as follows:

(1) From the damage of 12/13 July 1945 repairs would require approximately 2 months.

(2) From the damage of 25/26 July 1945 repairs would require approximately 3 months.

(3) From damage of 1/2 August 1945 repairs would require approximately 9 months.

b. No production had been reattained at the time of the inspection.

c. No portion of the plant could have been utilized because of the destruction of a portion essential to the entire plant.

4. Vulnerability

The vulnerability of all steam power plants is fully covered in the final report which is applicable to this plant.

Intelligence Check.

1. *a*. OSS report in general correctly identified and evaluated this plant.

b. The Air Objective Folder No 90.17 for the Tokyo Area, issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this plant as Target No. 493, correctly located it on maps, evaluated its importance, and gave a reasonably correct plot plan.

c. JTG information was essentially correct as to the significance, location, description, and layout.

2. Records of the raids in which this plant was damaged were covered in reports of raids 267, 291, 310, on Targets 116, 127, and 128 respectively.

a. Damage Assessment Report No 157, covering raids of 12/13 July 1945, does not list any damage to this plant, although aerial photographs clearly show a number of strikes and damage.

b. Damage Assessment Report No 173, covering raids of 25/26 July 1945 and 1/2 August 1945, does not list any damage, although aerial photographs clearly show a number of strikes and damage.

c. Damage Assessment Report No 184, covering raid of 1/2 August 1945, does not list any damage, although aerial photographs clearly show a number of strikes and damage.

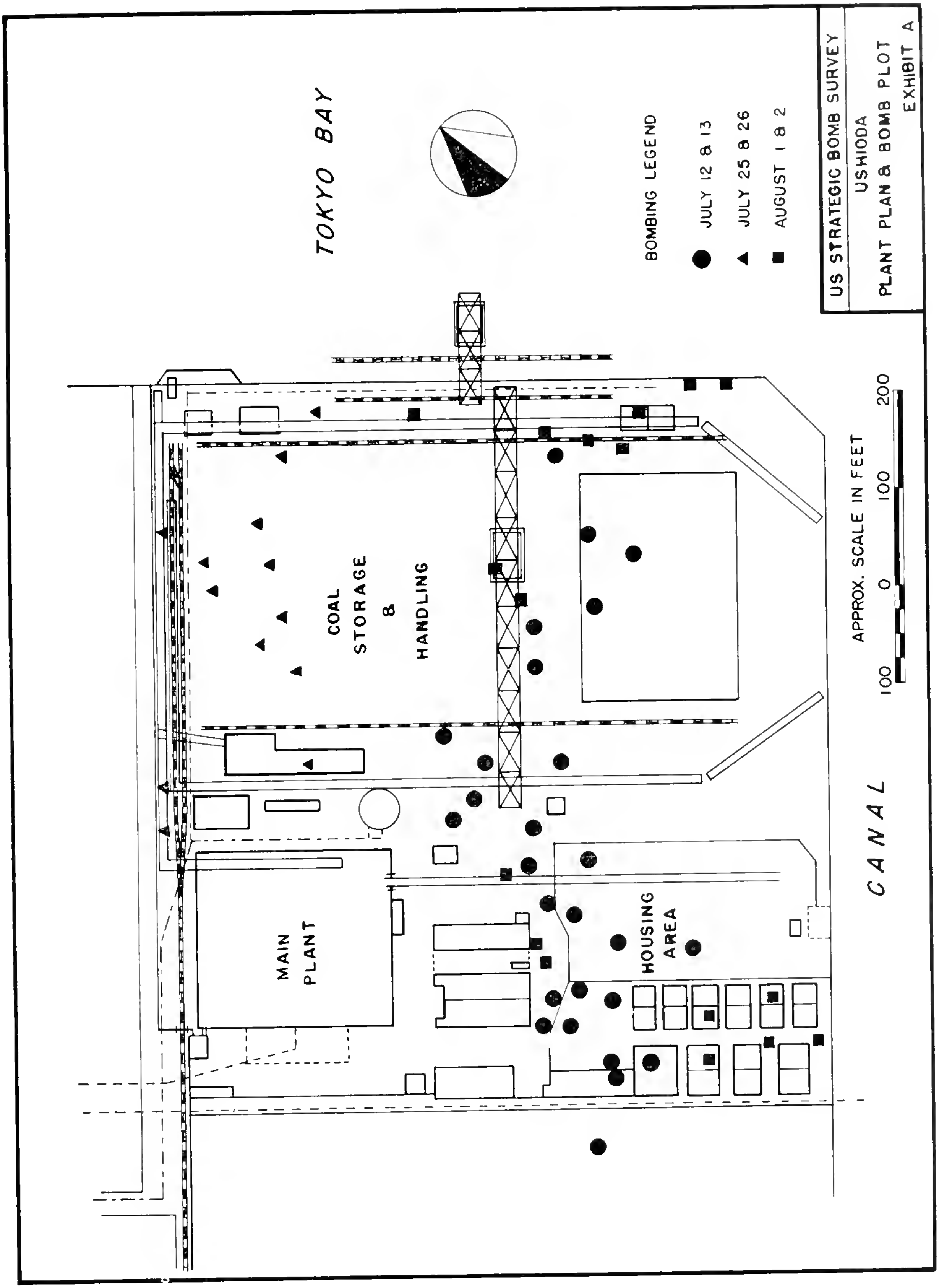
3. No mention was made in any damage assessment reports of recuperation or dispersal.

Data Relevant To Other Studies.

The shortage of coal and the necessity of using poor grade coal were due to transportation difficulties, especially the curtailment of barge transportation of coal.

Evaluation and Impression.

No effort is being made to repair or clean up any bomb damages.



US STRATEGIC BOMB SURVEY
USHIODA
PLANT PLAN & BOMB PLOT
EXHIBIT A
TOKYO BAY
BOMBING LEGEND
JULY 12 & 13
JULY 25 & 26
AUGUST 1 & 2
COAL
STORAGE
&
HANDLING
MAIN
PLANT
HOUSING
AREA
CANAL
APPROX. SCALE IN FEET
100
0
100
200

EXHIBIT B

Ushioda Steam Power Plant
Production in KWH

	1942	1943	1944	1945
Jan.	18,963,800	26,476,900	21,512,100	4,057,200
Feb.	15,750,400	15,335,000	18,901,200	14,689,800
Mar.	482,000	17,030,600	14,909,600	387,008
Apr.	0	2,672,600	2,224,900	0
May	1,188,300	1,090,500	0	0
June	6,292,000	1,667,900	634,300	0
July	6,915,000	4,935,500	1,574,300	0
Aug.	11,810,200	6,348,500	0	0
Sept.	5,112,000	2,736,200	2,767,900	0
Oct.	3,891,500	0	929,500	
Nov.	13,680,200	7,154,400	0	
Dec.	24,110,400	15,918,700	953,800	
Total	108,195,800	100,366,800	64,407,600	19,134,000

EXHIBIT C

Photo 1—Close up view of damaged buss-run

Photo 2—General view showing damage to busses and cables

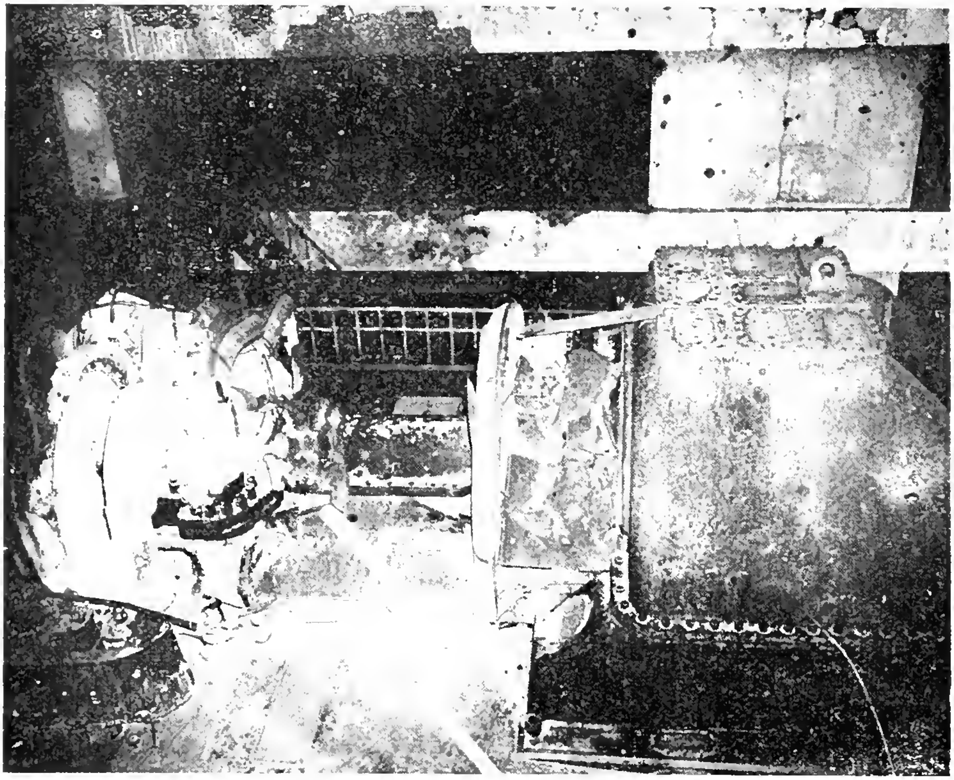


Photo 3—Damaged number 2 steam turbine

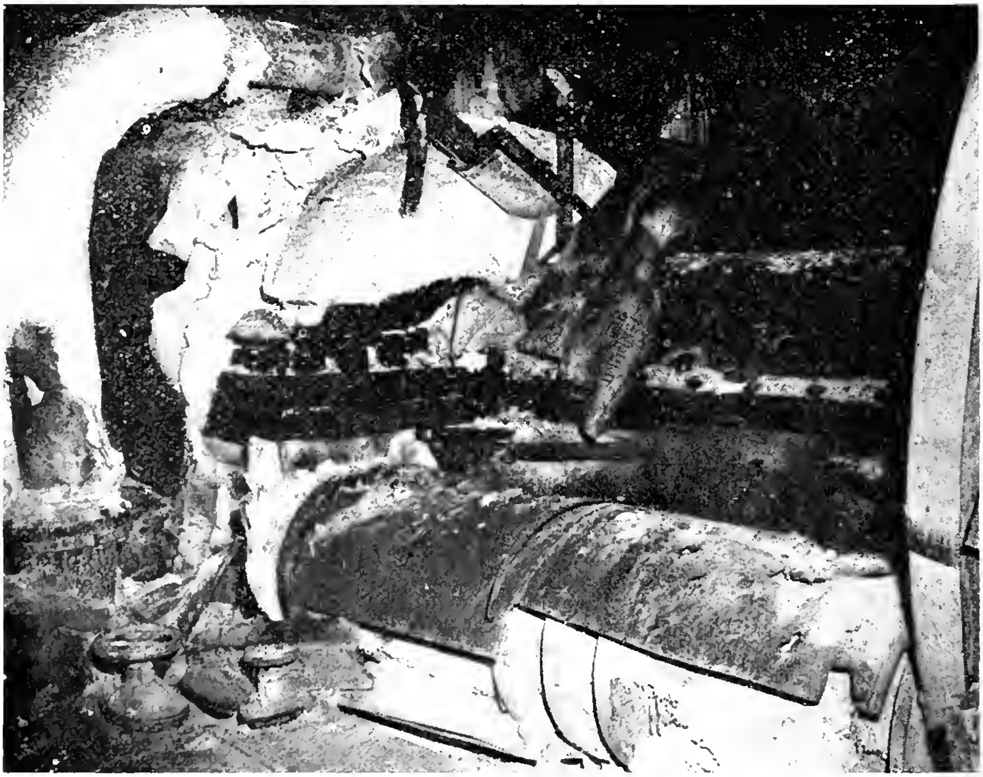


Photo 4—Close view of damaged number 2 steam turbine

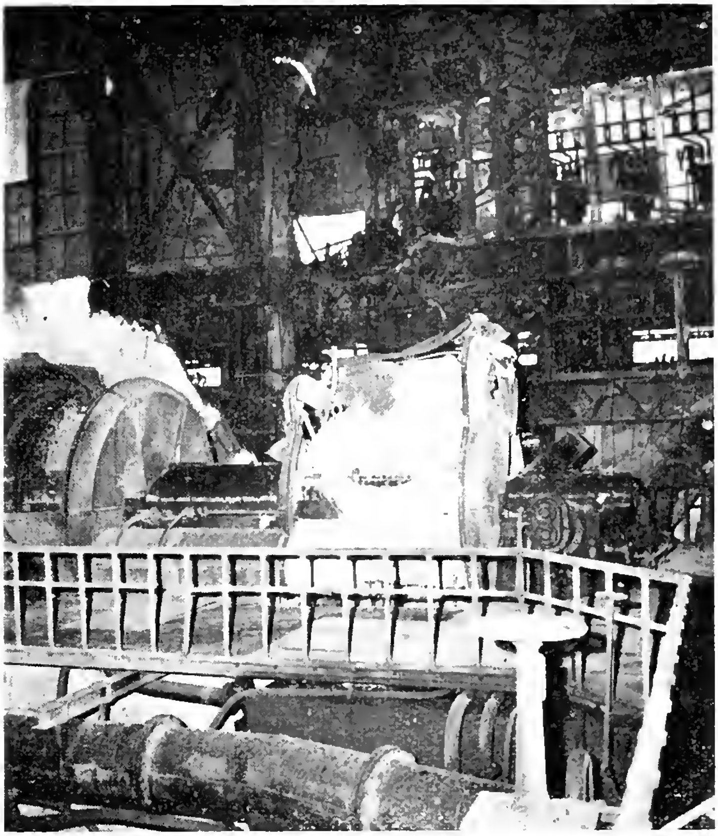


Photo 5—General view of blast effect in switch room and of number 2 steam turbine

Photo 6—Fragmentation effect in interior of generator hall

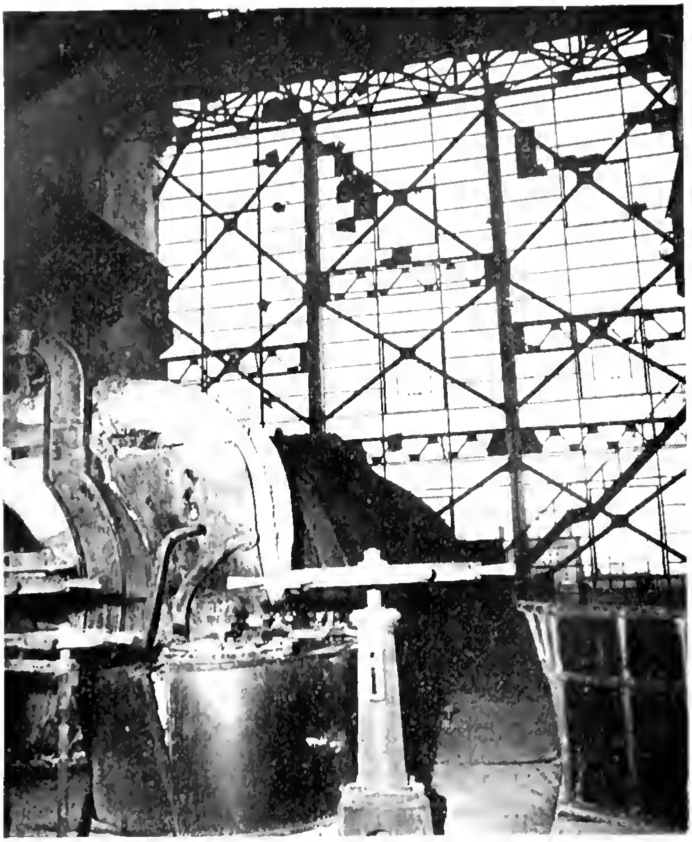


Photo 7—Fragmentation effect in interior of generator hall

Photo 8—Damaged crane scale in generator hall

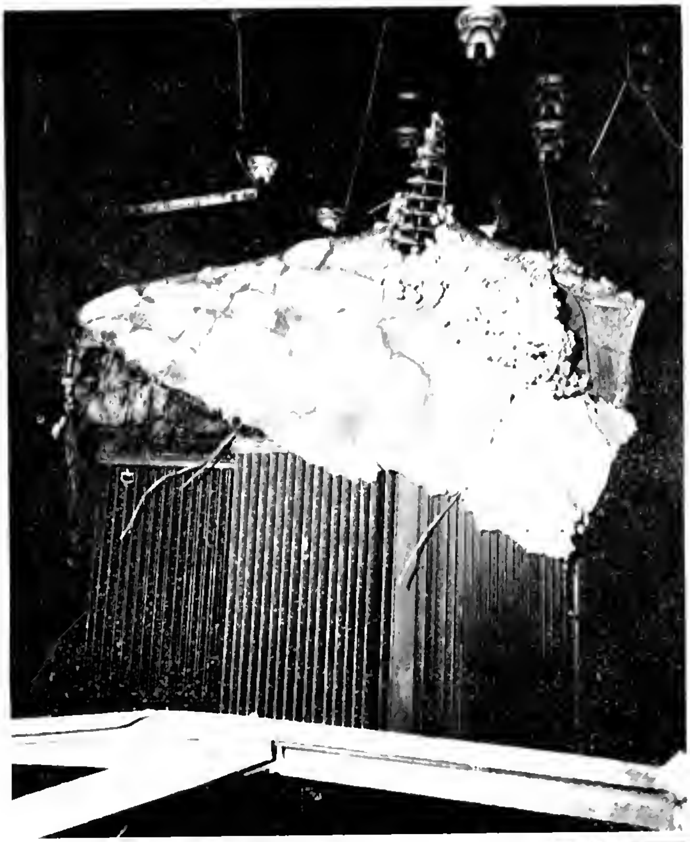


Photo 9—Damaged 13,750-KVA 3-phase transformer

Photo 10—Damaged exterior of building

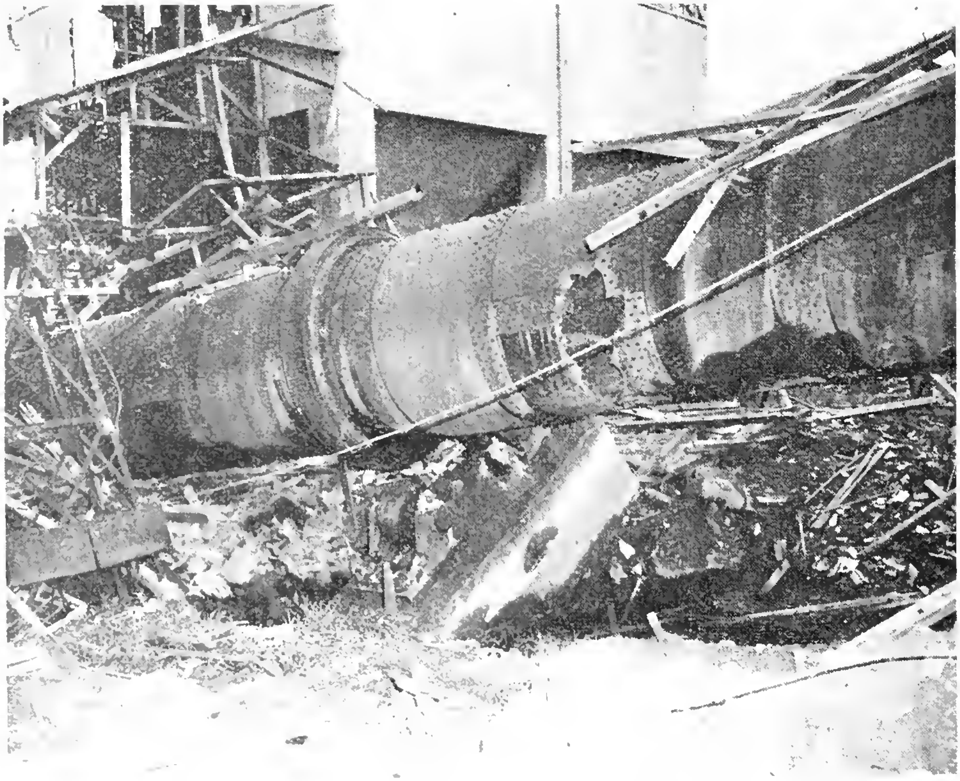


Photo 11—Damaged coal dryer and demolished water cooling inlet tunnel

SHIMOTAKI HYDRO POWER PLANT

KINU RIVER, JAPAN

DATE INSPECTED 21 OCTOBER 1945

Summary.

1. The Shimotaki Hydro Power Plant is located on the right bank of the Kinu River approximately 100 miles north of Tokyo and near the town of Nikko. It is typical of many similar plants located in this mountainous section, but is the largest in that area. It has at present 36,800 KW in name plate capacity. It is housed in 2 substantial, brick and concrete buildings, one of which houses the turbines and the other the switching equipment. This plant is a run-of-river type, but the diversion dam provided some storage capacity. Its yearly average output for the 3 war years was 120 million KWH. While its output was seasonal, it operated throughout the year, and its minimum monthly generation was 38.7 percent of its maximum month. The energy was delivered to the transmission lines of the Japan Electric Generation and Transmission Company for general distribution, but its particular importance was to supply Tokyo and vicinity.

2. This plant was never a primary target, nor was it ever damaged by any war action.

3. There was no physical damage or production loss during the war. The plant had good security from attack because of its obscure location on a shelf of a mountain, but the long, exposed penstocks were especially vulnerable, and damage to them would have been vital to plant operation. In case of damage, recuperation would have been long and difficult.

4. Intelligence data was accurate.

5. While the size of this particular plant and the exposed position of its vital penstocks might have made it a feasible target, the best method of destroying power supply from sources of this nature would be to attack and eliminate main substations, usually located elsewhere, where electric energy is collected from a number of hydro plant sources.

The Plant and Its Function In Enemy Economy.

1. Product of plant and importance in enemy economy.

This plant is the largest and most important one of a group of similar plants located in the same area and is typical of them all in operation and general characteristics. It is a run-of-river type, with a small amount of storage built up by a diversion dam. Therefore, the plant attains maximum output during the wet season, but there is sufficient river run and storage available to provide a certain amount of generation throughout the entire year. The following table gives maximum and minimum production, the months in which they occurred, and percentage of minimum to maximum.

Expressed in million KWH

	1942	1943	1944	Average
Maximum	16.0 (May)	14.1 (Sept.)	12.5 (June)	14.2
Minimum	5.8 (Feb.)	5.5 (Feb.)	5.2 (Feb.)	5.5
Percent	36.2	39	41.6	38.7

The plant generated the following KWH:

1942	1943	1944	*1945
123,397,600	123,952,700	113,155,500	48,320,200

*Through August only.

This plant delivered its output to the Japan Electric Generation and Transmission Co lines for general distribution, but the output was primarily utilized in the Tokyo area. The production was not of sufficient size to be of importance in itself, since the capacity and production were each only six-tenths of one percent of the capacity and annual production of all the hydro plants of the Japan Electric Generation and Transmission Company. It is typical of the hydro power plant situation in Japan.

2. Physical description of plant.

a. The plant is located on a rectangular plot of ground on the right bank of the Kinu River. About 100 ft in front of the plant the plot drops off in a deep gorge, and immediately behind, the ground rises to a high elevation. There are 2 brick and concrete buildings, 2-stories in height and with a peak roof construction. One building houses the turbogenerators, and the other, at right angles, is the switch house. This latter building has a coat of camouflage paint. The source of water supply is the Kinu River. Far upstream, there is a stone, overflow, gravity, diversion dam from which water is brought through an aquaduct approximately 9 miles long to a forebay. From this, there are 4 penstocks approximately 3300 ft in length to the plant. The head is 1068 ft and maximum water flow is 540 cu ft sec. There are 4 units,

each consisting of a horizontal-type generator driven by 2 impulse-type turbines on a common shaft, each turbine with a separate governor. The equipment was originally furnished by Escher Wyss in 1913 for 25-cycle operation, but was replaced in 1935 by Tokyo Shibaura with equipment for 50-cycle. Each unit is rated 11,500-KVA at 80 percent power factor, making a total for the plant of 36,800 KW. There was one additional unit, but it was removed in May of 1945 because of insufficient water supply.

b. The source of power is the Kinu River and the natural gravity drop from the diversion dam to the plant. Normally there are dry and wet seasons, but the rainfall is such that some water is available throughout the year with the result that the plant had a dry season minimum output equal to 38.7 per cent of the wet season maximum.

3. The plant was originally owned by the Kinu River Hydro Electric Company, which built the plant. It was taken over and is now owned by the Japan Electric Generation and Transmission Company. Mr. T. Ishiwara is chief operator and supplied most of the information concerning this plant.

4. The plant has 10 employees. There are 4 men per shift of 12 hours each, and during the daytime shift there are, in addition to the regular operators, a chief operator and a female telephone operator.

Attacks.

There were no attacks on the plant at any time during the war, nor was it ever a primary target.

Effects of Bombing.

1. Physical damage.

   There was no physical damage from any war action.

2. Production loss.

   There was no production loss from any direct cause.

3. Recuperability cycle.

Since there was no damage, there is no measure of recuperability, but, had the plant been damaged, repairs would have been difficult and time-consuming because of its inaccessibility.

4. Vulnerability.

This plant was provided with good security from attack because of its obscure location on the shelf of a mountain. However, it was susceptible to damage as is any hydro plant, and especially the long exposed penstocks which are visible for some distance from the air. An attack concentrated on the aquaduct or penstocks would effectively put the plant out of commission and could easily cause a flood which would seriously damage the power plant and its equipment.

Intelligence Check.

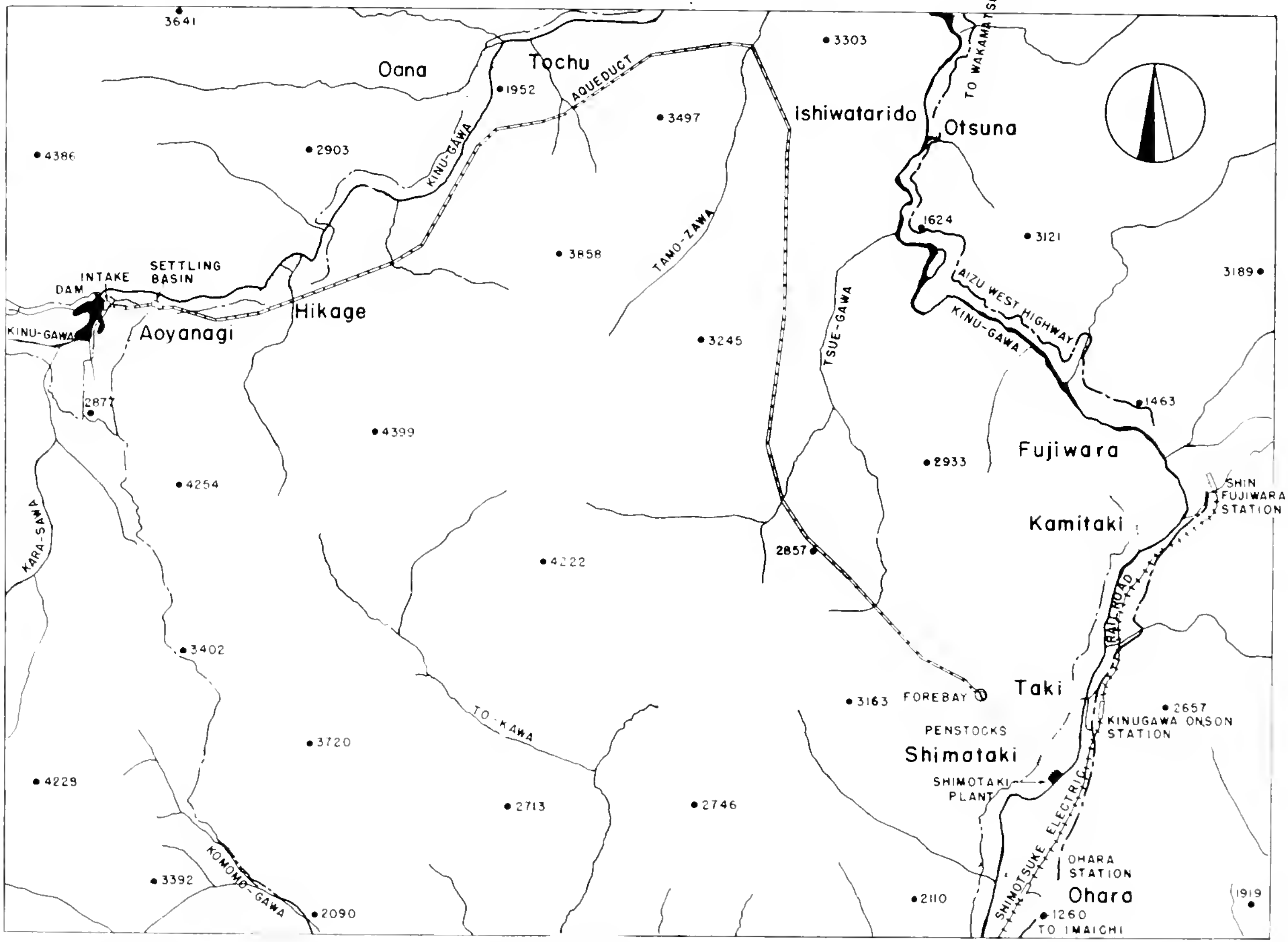
The OSS reports and other data accurately describe the plant, its location, and physical characteristics, but the equipment shown was somewhat at variance with actual fact.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

The long penstocks offered a good and effective means of serious damage, but, on the other hand, the obscure location of the plant made it reasonably secure from possible attack. This plant is typical of many Japanese hydro plants and shows that the most effective and successful way of eliminating power supply from these sources would be to attack and destroy main substations where the supply is collected from a number of hydro plants.



SETTLEMENT CENTER
PRINCIPAL HIGHWAY
SECONDARY ROAD
RIVERS & STREAMS
SPOT ELEVATION IN FEET
1 0 MILES 1 2

US STRATEGIC BOMB SURVEY
SHIMOTAKI
HYDRO-PLANT
EXHIBIT A

697713—47—7

Photo 1—Takatoku Dam, Railway bridge, and highway bridge

Photo 2—Shimotaki Plant showing penstocks on the hill

PLANT REPORT NUMBER 14

HIDA RIVER HYDRO POWER PLANTS

HIDA RIVER (CENTRAL HONSHU), JAPAN

DATE INSPECTED 12 NOVEMBER 1945

Summary.

1. The group of 9 hydro plants, located on the Hida River north of Nagoya, has approximately 200,000 KW installed generator capacity. The plants are in substantial concrete buildings with adjacent outdoor transformer and switching stations. Although concrete diversion dams provide some storage capacity, they are principally run-of-river type plants. Maximum production was attained during the wet season, but there was continuous operation, and the minimum dry season month's production averaged 39.5 percent of the wet season maximum. Their yearly output averaged slightly over one billion KWH per year during the 3 war years. The energy was utilized principally by the highly industrialized areas of Nagoya and Osaka, which were highly important in the war economy.

2. These plants were never a primary target nor were they ever damaged by any war action.

3. There was no physical damage or production loss during the war. Recuperation would have been slow in case of damage, partly because of their inaccessibility. These plants are not considered very vulnerable due to their location. However, they are, as are all hydro plants, highly susceptible to damage.

4. Intelligence information was not good.

5. This study shows definitely that an attack on this type of plant would be impractical and that the most feasible method of rendering the average hydro plant incapable of production is to attack and eliminate main substations located elsewhere, which are the collecting points for a number of plants.

The Plants and Their Functions In Enemy Economy.

1. This report covers a group of hydro plants forming the hydro power developed on the Hida River. The plants and their generating capacities are given in the table below:

Capacities in KW

	Name plate capacity KW	Rated capacity KW
Osaka	16,000	18,000
Seto	49,000	48,000
Shimohara	21,000	22,000
Ofunato	6,400	6,400
Shichiso	6,000	6,150
Nagura	20,000	22,200
Kamiazo	24,300	27,000
Kawabe	26,400	30,000
Imawatari	20,000	20,000
Total	189,100	199,750

Because of the ability in most instances to secure from the plant more than the actual name plate ratings, the government has given each plant a rated capacity which the plant, under conditions of necessity, and with maximum water supply available, could attain. This is known as the government licensed rating, and therefore the total obtainable capacity at these plants is 199,750 KW.

This group of plants generated the following KWH annually during the war years:

	1942	1943	1944	1945*
Osaka	112,511,300	111,868,000	113,056,100	39,635,400
Seto	239,929,400	265,214,900	258,381,200	138,688,300
Shimohara	91,156,000	104,513,200	96,678,200	45,125,800
Ofunato	18,215,400	22,125,300	23,655,600	7,799,000
Shichiso	36,801,100	36,202,900	38,167,100	8,500,800
Nagura	114,503,200	110,418,800	106,413,200	45,182,700
Kamiazo	159,758,600	162,858,100	169,908,300	59,404,100
Kawabe	111,494,800	109,307,000	99,979,700	49,279,000
Imawatari	101,856,000	95,530,800	100,416,600	54,877,900
Totals	986,225,800	1,018,039,000	1,006,656,000	448,493,000

NOTE—*Through August.

These plants are run of river type, and therefore maximum generation is attained during the wet season. There is a small amount of storage built up by the diversion dams, and there is sufficient river run and storage available to provide a certain amount of generation throughout the year. The following table gives maximum and minimum production, the months in which they occurred and percentage of minimum to maximum:

Expressed in Million KWH

	1942	1943	1944	Average
Maximum	115.7 (March)	117.2 (April)	121.1 (April)	118.0
Minimum	53.4 (Dec.)	44.0 (Jan.)	42.6 (Feb.)	46.6
Percent	46.1	37.5	35.2	39.5

The total capacity of these plants represent 3.4 percent of all hydro generating capacity and 2.3 percent of all public generating capacity in Japan. In 1943, these plants generated 3 percent of all generation in Japan, 3.6 percent of all hydro generation in Japan, and 5 percent of all hydro generation of the Japan Electric Generation and Transmission Co.

The generated current is delivered to various transmission lines of the Japan Electric Generation and Transmission Co. and was primarily utilized in the Nagoya and Osaka Area.

2. Physical description of plant.

a. The Hida River is one of many rivers located in the mountainous regions of central Honshu lying approximately between 35°30′ to 36°00′ latitude and 137°10′ longitude. It is about 65 miles in length from the source to the location of the last plant. The head, discharge, and relative positions of these plants are shown in Exhibit A, and the location of plants, dams, tunnels, and so forth, is shown in Exhibit B. All the plants are, in general, of the same type with features common to all hydro plants. Two plants were inspected, namely the Seto and Kawabe plants.

The Seto plant is known as Seto No 1 and No 2; however, the entire plant is actually in one building, although the source of water is different. Seto No 1 receives its water from the Masuda branch of the Hida River and No 2 from the Mase and Ugake branch of the same river. The first part (Seto No 1) was constructed in 1923. It has an effective head of 335 ft and uses a maximum of 1,110 cu ft/sec. Water from the river is diverted by a low concrete dam upstream from the plant into an open canal and thence through a tunnel to the penstock head gates. No appreciable volume of water is stored by the dam. There are 4 exposed penstocks leading to the plant, in which are 4 EW, vertical-axis, Francis turbines, each with a 6,750-KW, Westinghouse generator. The second part (Seto No 2) was constructed in 1938. It has an effective head of 525 ft and uses a maximum of 550 cu ft/sec. From the Mase branch, water is diverted to the Ugake branch across which is a concrete dam approximately 250 ft in length and 64 ft in height which impounds approximately 7 million cu ft of water. From this dam, water is brought through a tunnel to the penstock head gates and through 2 exposed penstocks to the plant (Exhibit C, photo 3). There are 2 Mitsubishi, vertical-axis, Francis turbines each with a 11,000-KW, Mitsubishi generator. There is a common control room (Exhibit C, photo 2) for the entire plant and a common outdoor switching and transformer station (Exhibit C, photo 1), which is connected to the 154-KV line leading to the Kitakata and Sasazu substations. Complete engineering data on this plant are in the USSBS files.

The Kawabe plant was constructed in 1937. It obtains its water from the Hida River and has an effective head of 77 ft with a discharge of 5,500 cu ft/sec. Water from the river is diverted by a concrete dam (Exhibit C, photo 4) through a diversion canal head race (Exhibit C, photo 5) to the head gates (Exhibit C, photo 6). The dam is primarily a diversion dam; however, it stores approximately 42,000,000 cu ft of water. There are three penstocks completely concealed beneath concrete masonry (Exhibit C, photo 8). In the plant, there are 3 Francis-type turbines, and generators manufactured by Hitachi. Each is rated 11,000-KVA at 80 percent P F or 8,800-KW; however, a total plant capacity of 30,000 KW has been attained, and the plant is so rated in the records. There is one control room and an outdoor transformer and switching station (Exhibit C, photos 7 and 8). This station is the terminal of a 77-KV line from a number of other upstream plants and transforms to a 154-KV line going to the Iwakura substation. Complete engineering data on this plant are in the USSBS files.

These 2 plants are typical of the other hydro plants on the Hida River. Photographs of the Shimohara plant and its storage and diversion dam are shown in Exhibit C, photos 9 and 10.

b. The source of power is the Hida River watershed, and except for small storage from dams principally used as diversion dams, the plants are run-of-river type. As such, their principal output was during the wet season, but the load data show that even in the dry season the plants were in a position to generate an average of 39.5 percent of their maximum. The usable hydro storage was governed by orders issued by the Electric Power Bureau as determined by other governmental agencies. No change in power source occurred during the war because of any war action.

3. The plants are owned by the Japan Electric Generation and Transmission Co. Information was obtained from:

Mr. S. Saito —Director and district mgr of Tokai district, Japan Electric Generation and Transmission Co., in which these plants are located.
Mr. Imura —Chf engr for the district.
Mr. R. Koto —Chf engr for the Seto plant.
Mr. H. Okozono—Chf engr for the Kawabe plant.

4. The Seto plant normally uses 32 employees, and the Kawabe plant uses 18. The total for the entire Hida River plants is approximately 300 employees. They work 2 shifts and are used continuously throughout the year.

Attacks.

None of the Hida River hydro plants was ever subject to attack, and there was no damage from any type of war action.

Effects of Bombing.

1. Physical damage.

Since there was no damage, no study of bombing effects could be made.

2. Production loss.
   There was no production loss.
3. Recuperability cycle.
   No damage occured, and therefore no recuperability could be determined; however, since these hydro plants, like most of the hydro plants in Japan, are located in very remote and inaccessible places, the recuperability time would be considerably longer than normal.
4. Vulnerability.

Hydro plants are vulnerable from the standpoint of their susceptibility to bomb damage. In particular, damage could be inflicted on penstocks or outdoor switching and transformer stations that would render the plants inoperative for a long period. However, hydro plants are generally located in inaccessible places in very mountainous country and would have to be bombed from a high level. The small size of the buildings and the large number of the plants would make effective bombing very difficult. Therefore, the vulnerable points for these plants, as well as other hydro groups, are at the substations which collect and redistribute their generated current.

Intelligence Check.

1. *a.* OSS reports in general correctly identified and evaluated these plants with the following exceptions:

   (1) The Seto Plants were listed as 2 separate plants, namely, Seto No 1 and Seto No 2; whereas they are one plant as OSS photograph No IV-108 clearly shows.

b. The Air Objective Folder 90.20 for Nagoya Area listed the Seto plant but none of the others. The information given was correct but meager and the photographs old and obsolete. Target No. 1161 had been assigned to this plant.

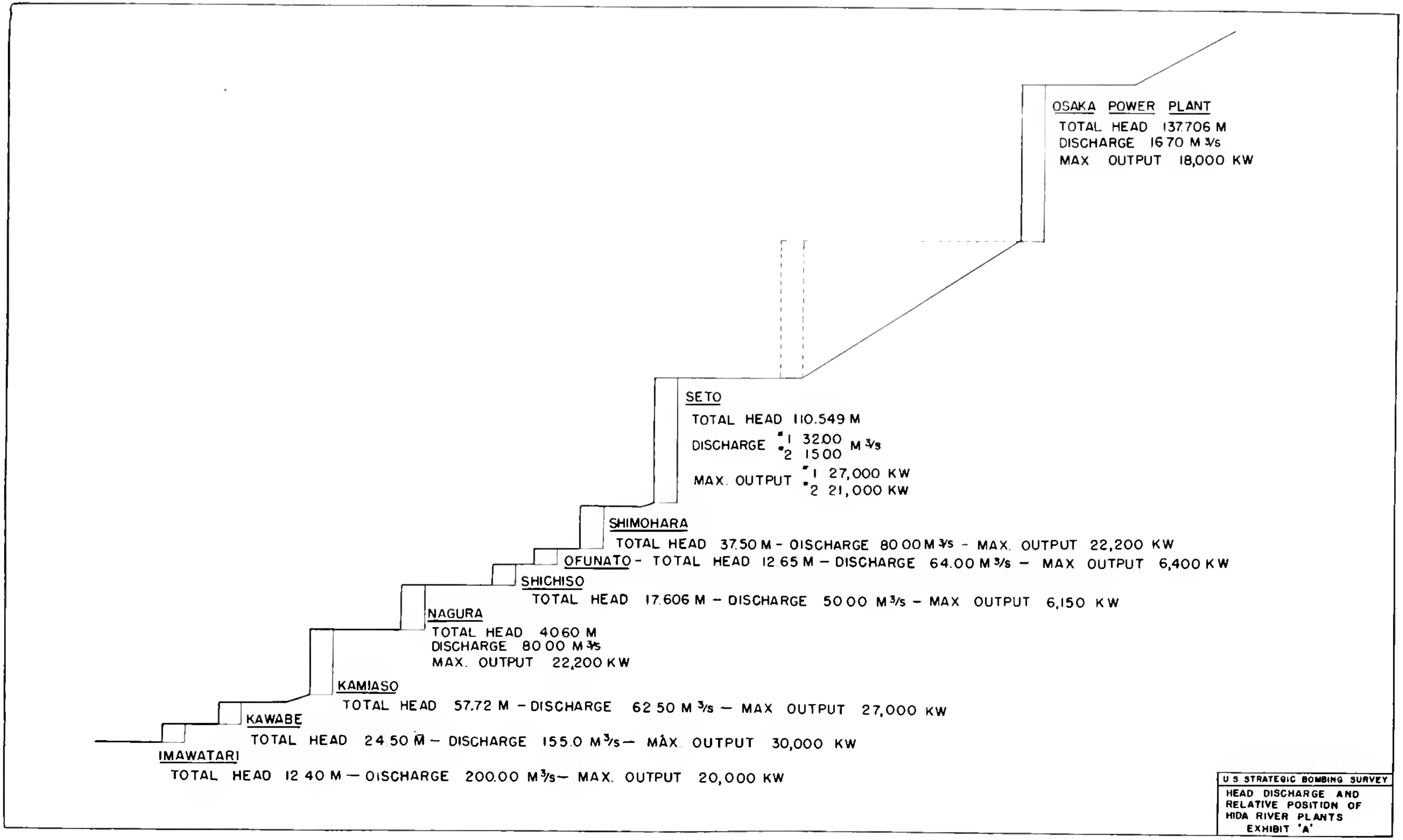
c. None of these plants was listed by JTG.

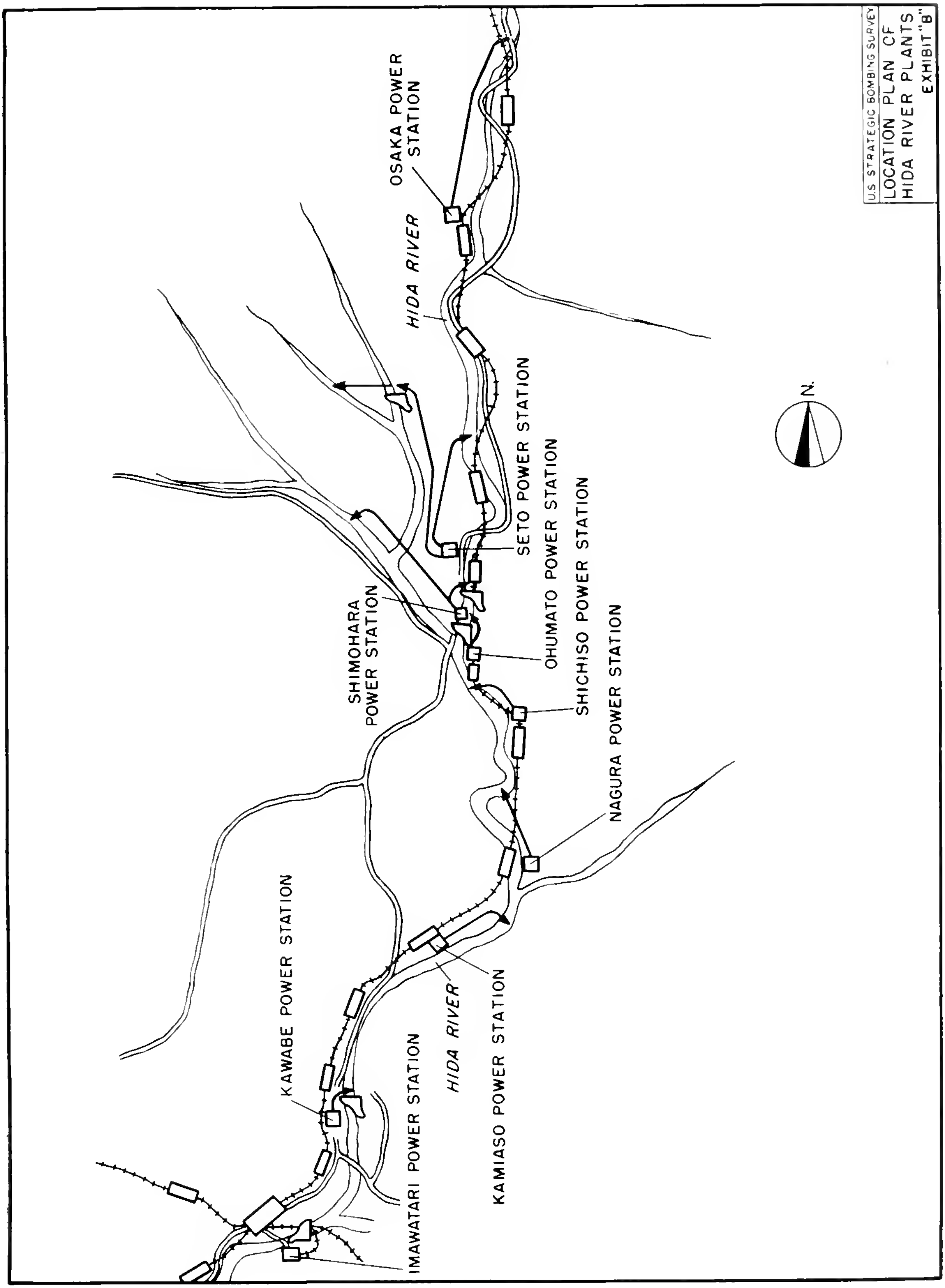
Data Relevant To Other Studies.

None.

Evaluations and Impressions.

These plants are modern and maintenance is good. The natural resources of this river are developed in an excellent manner. The Electric Power Bureau with the other interested bureaus, such as Agriculture and Forestry, had set limitations on the low water point on the storage reservoirs, in order to insure a constant water supply for other purposes. During the war, the electric energy requirements were such that exceptions were made, and water was utilized far below this minimum on several occasions.


OSAKA POWER PLANT
TOTAL HEAD 137.706 M
DISCHARGE 16.70 M³/s
MAX OUTPUT 18,000 KW
SETO
TOTAL HEAD 110.549 M
DISCHARGE #1 32.00 #2 15.00 M³/s
MAX. OUTPUT #1 27,000 KW #2 21,000 KW
SHIMOHARA
TOTAL HEAD 37.50 M - DISCHARGE 80.00 M³/s - MAX. OUTPUT 22,200 KW
OFUNATO - TOTAL HEAD 12.65 M - DISCHARGE 64.00 M³/s - MAX OUTPUT 6,400 KW
SHICHISO
TOTAL HEAD 17.606 M - DISCHARGE 50.00 M³/s - MAX OUTPUT 6,150 KW
NAGURA
TOTAL HEAD 40.60 M
DISCHARGE 80.00 M³/s
MAX. OUTPUT 22,200 KW
KAMIASO
TOTAL HEAD 57.72 M - DISCHARGE 62.50 M³/s - MAX OUTPUT 27,000 KW
KAWABE
TOTAL HEAD 24.50 M - DISCHARGE 155.0 M³/s - MAX. OUTPUT 30,000 KW
IMAWATARI
TOTAL HEAD 12.40 M - DISCHARGE 200.00 M³/s - MAX. OUTPUT 20,000 KW
U S STRATEGIC BOMBING SURVEY
HEAD DISCHARGE AND RELATIVE POSITION OF HIDA RIVER PLANTS
EXHIBIT 'A'


U.S. STRATEGIC BOMBING SURVEY
LOCATION PLAN CF
HIDA RIVER PLANTS
EXHIBIT "B"
OSAKA POWER STATION
HIDA RIVER
SETO POWER STATION
OHUMATO POWER STATION
SHIMOHARA POWER STATION
SHICHISO POWER STATION
NAGURA POWER STATION
KAWABE POWER STATION
HIDA RIVER
KAMIASO POWER STATION
IMAWATARI POWER STATION
N.

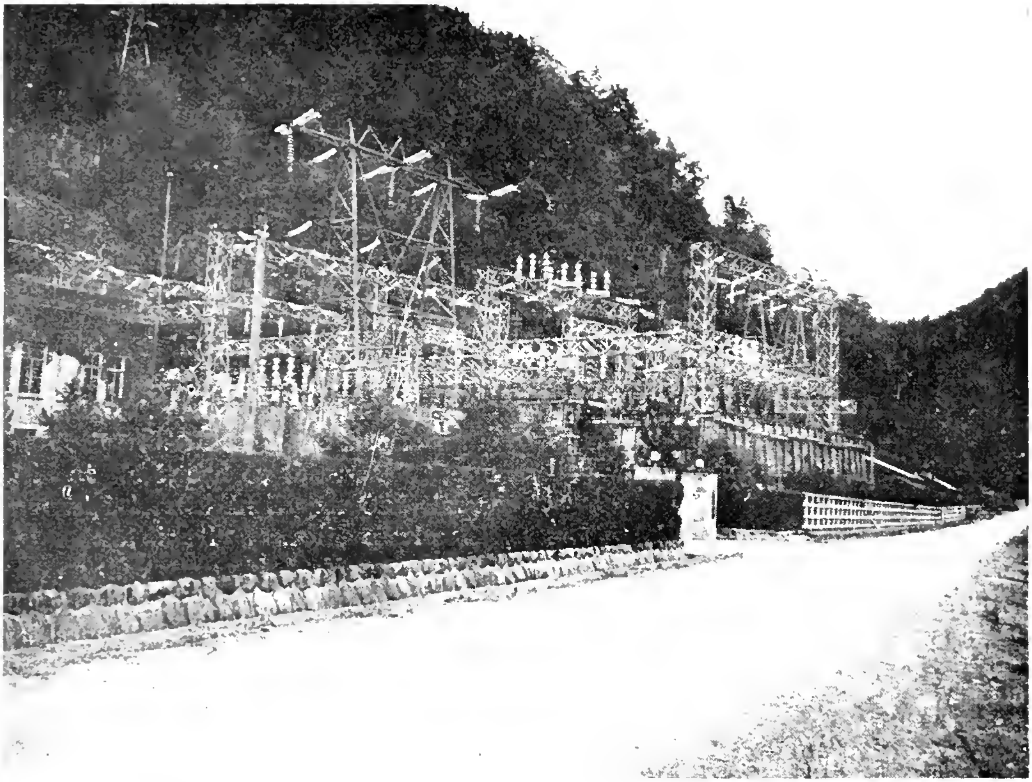


Photo 1—Seto Plant Outdoor switching and transformer station. Note blast protection barriers. Edge of camouflaged plant at left of picture

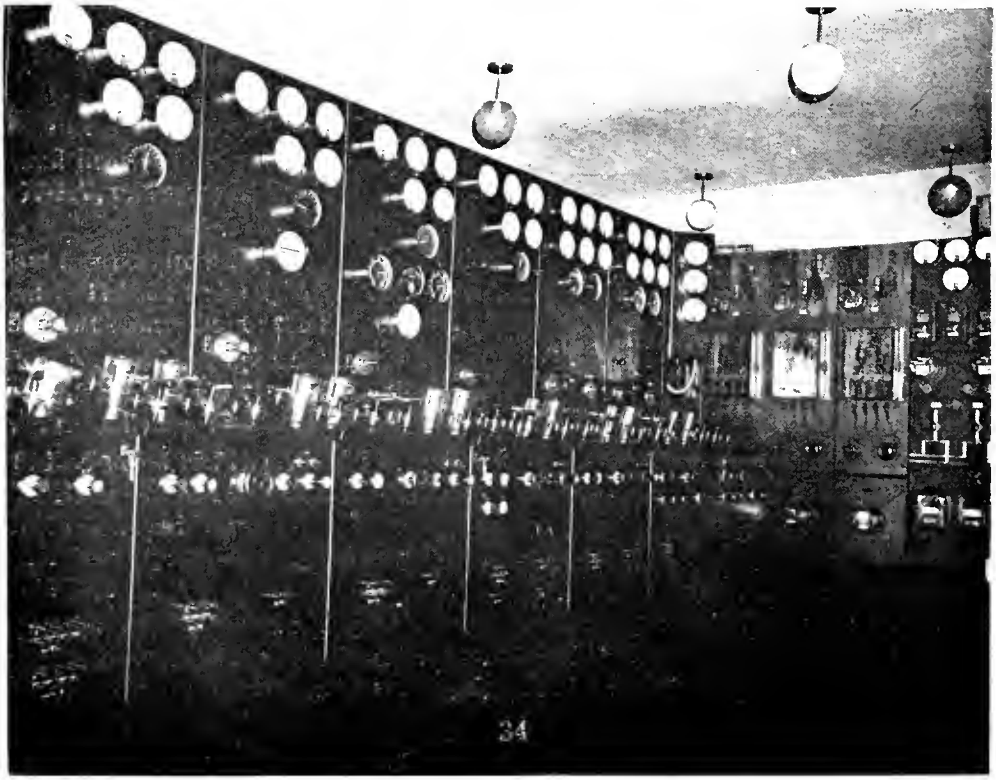


Photo 2—Seto Plant—Interior view control board

Photo 3—Seto Plant—Exposed penstocks to No 2 section

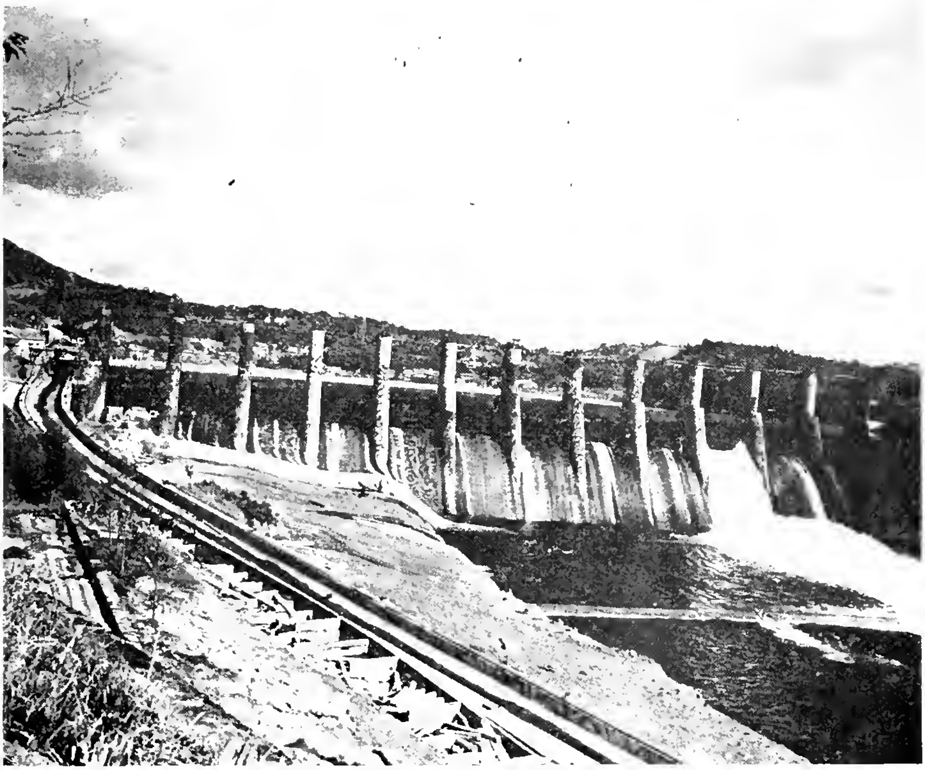


Photo 4—Kawabe Plant—Storage and diversion dam on Hida River—Note camouflage

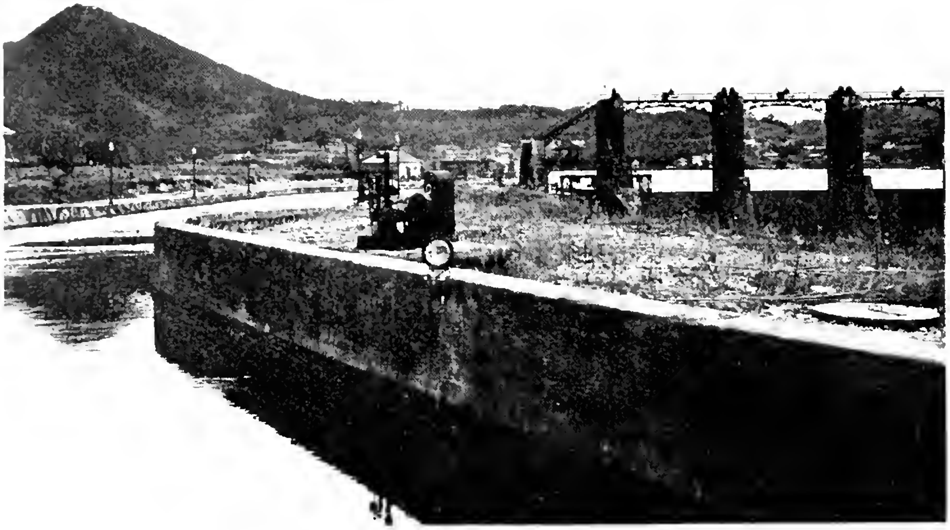


Photo 5—Kawabe Plant—Head race

Photo 6—Kawabe Plant—Diversion canal head gates

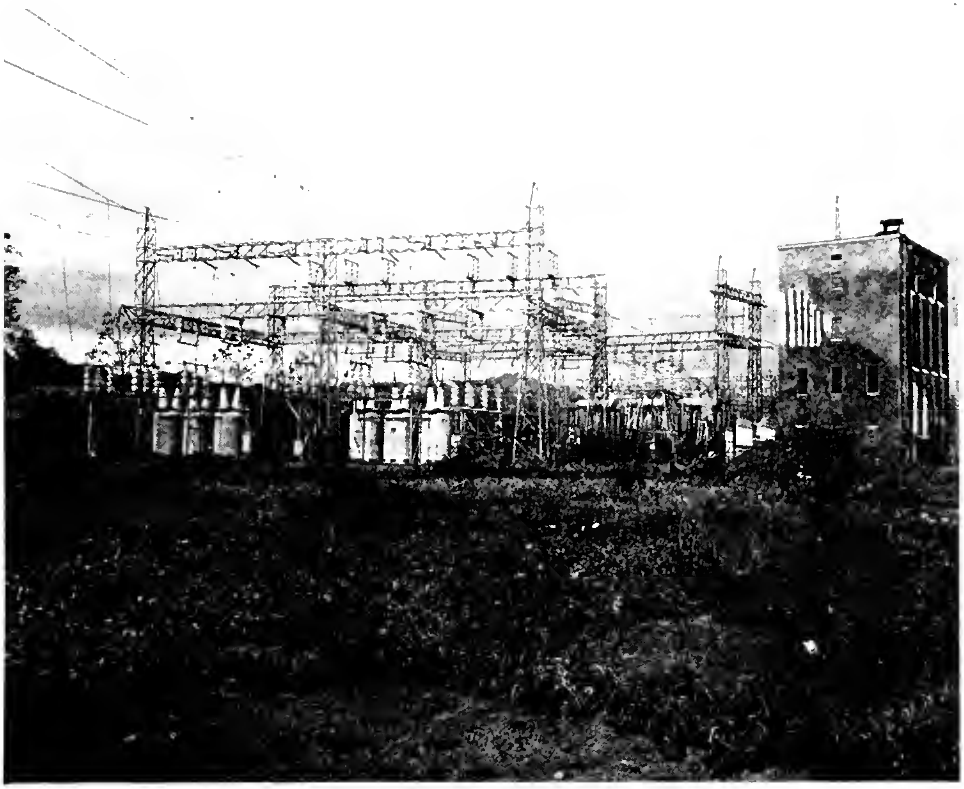


Photo 7—Kawabe Plant—General view outdoor switching and transformer station

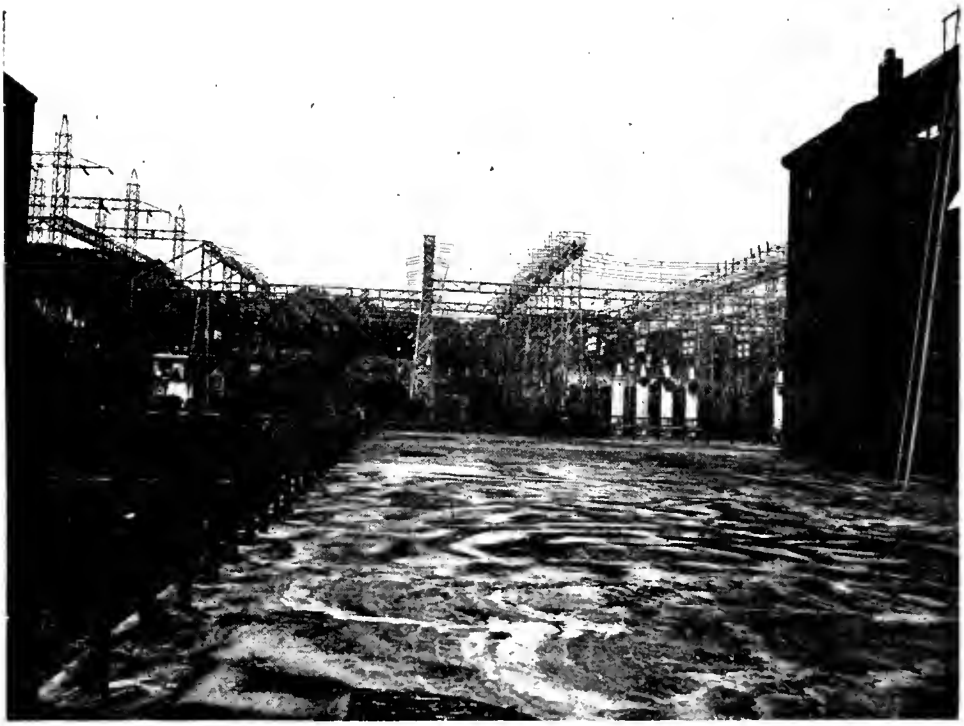


Photo 8—Kawabe Plant—Outdoor switching and transformer station taken from top of penstock inlet. Note protection barriers around main transformers

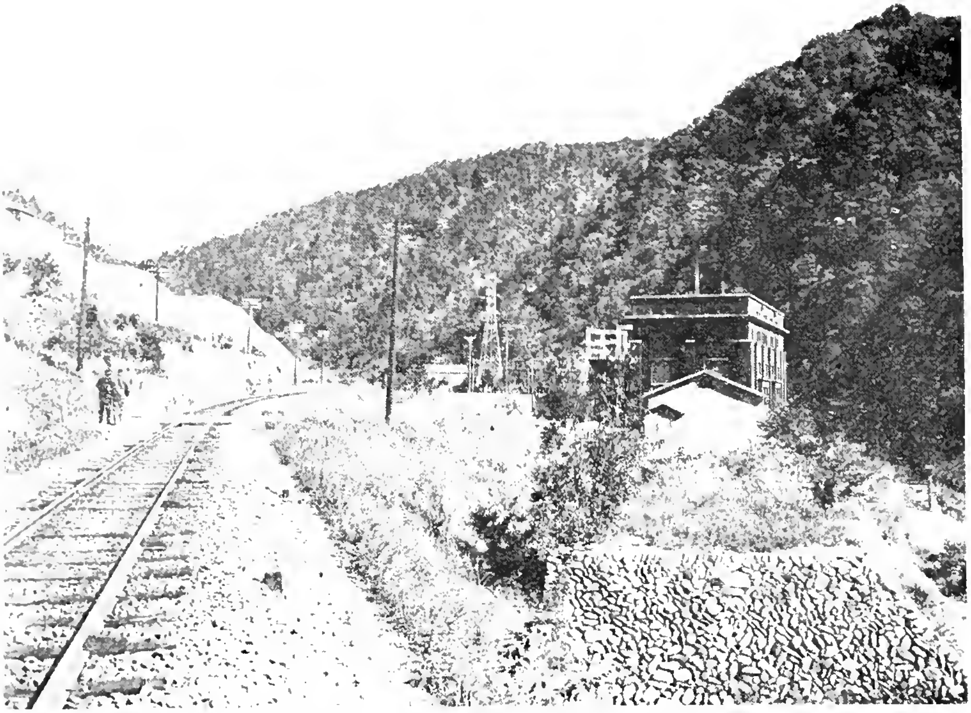


Photo 9—Shimohara Plant—General view. Buried penstocks are under stone masonry and railroad. Headgates are on extreme left top; tail race on extreme right bottom into Hida River

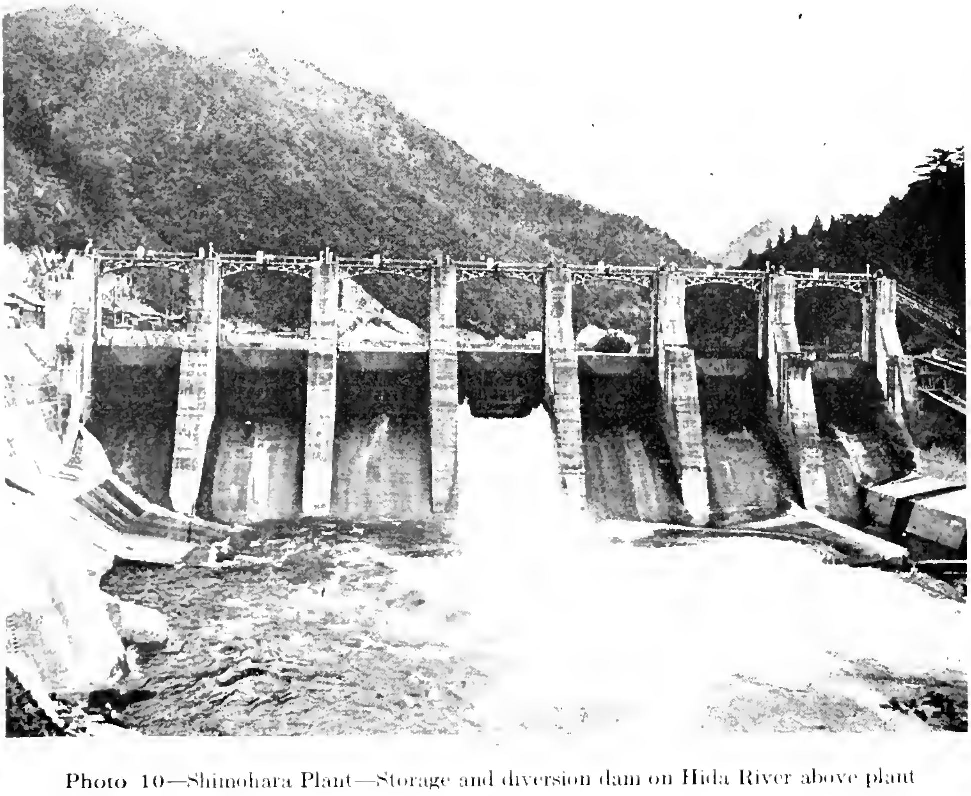


Photo 10—Shimohara Plant—Storage and diversion dam on Hida River above plant

KISO RIVER HYDRO POWER PLANTS

KISO RIVER (CENTRAL HONSHU) JAPAN

DATE INSPECTED 2-3 NOVEMBER 1945

Summary.

1. The group of 13 hydro plants, located on the Kiso River north of Nagoya, has 307,700 KW name plate generator capacity, or 324,700 KW government rated capacity. In addition, there is 18,000-KW plant under construction. The plants are in substantial concrete buildings with adjacent outdoor transformer and switching stations. Concrete dams are used for both diversion and storage, and there are approximately 106 million KWH of storage capacity. Maximum output is during the wet season, but their average output during the dry season is 40 percent of capacity. Their yearly output averaged 1,300 million KWH during the 3 war years. The energy was utilized by the highly industrialized areas of Nagoya and Osaka which were very important in the war economy. However, 5 of the plants were double frequency, so their energy could be supplied to either the 50- or 60-cycle area.

2. These plants were never a primary target nor were they ever damaged by any war action.

3. There was no physical damage or production loss during the war. Recuperation would have been slow in case of damage, partly because of inaccessibility. These plants are not considered very vulnerable, because of their location; however, they are, like all hydro stations, highly susceptible to damage.

4. Intelligence information was not good.

5. This study shows definitely that an attack on this type of plant would be impractical, and that the most feasible method of rendering the average hydro plant incapable of production is to attack and eliminate main substations located elsewhere which are the collecting points for energy from a number of plants.

The Plants and Their Functions In Enemy Economy.

1. This report covers a group of hydro plants forming the hydro power developed on the Kiso River. The plants, their generating capacities, and completion dates are given in the table above:

Name of plant	Name plate capacity KW	Government rated capacity KW	Completed date
Miura	7,500	7,500	January 1945.
Ontake	22,000	22,000	June 1945.
Tokiwa	13,600	14,600	July 1941.
Nezame	32,000	35,000	September 1938.
Momoyama	24,000	24,600	November 1923.
Suhara	9,200	10,000	July 1922.
Okuwa	12,000	12,100	August 1921.
Yomikaki	40,800	42,100	December 1923.
Shizumo	15,000	16,300	October 1919.
Ochiai	14,400	14,700	November 1926.
Oi	44,000	48,000	November 1936.
Kasagi	36,000	40,500	November 1936.
Kaneyama	37,200	37,100	March 1944.
Total	307,700	324,700	

Because of the ability in most instances to secure more than actual name plate ratings, the government has assigned to each plant a rated capacity which the plant, under conditions of necessity and with maximum water supply, could attain. This is known as the government licensed rating, and therefore the total obtainable capacity of these plants is 324,700 KW.

This group of plants generated the following KWH annually during the war years:

Name of plant	1942	1943	1944	*1945
Miura (started Jan 45)				4,449,800
Ontake (no operation)				
Tokiwa	53,592,700	54,003,100	52,966,200	22,781,820
Nezame	155,540,800	144,270,700	150,913,700	72,206,600
Momoyama	149,905,000	149,539,000	150,737,000	66,378,000
Suhara	71,200,600	56,011,000	60,291,100	18,744,600
Okuwa	79,750,400	80,912,200	82,357,500	40,452,300
Yomikaki	257,895,000	254,377,000	250,234,000	121,650,000
Shizumo	110,971,300	113,664,900	104,712,800	43,906,900
Ochiai	68,789,600	62,132,100	70,488,300	26,380,100
Oi	184,377,012	188,498,000	167,108,500	95,268,000
Kasagi	142,026,900	129,950,000	130,831,000	83,058,000
Kaneyama (started Aug. 43)		20,926,000	124,389,000	64,805,000
Totals	1,274,049,312	1,254,284,000	1,345,029,100	660,081,120

*Through August.

These plants are run-of-river type, and therefore maximum generation is attained during the wet season. However, there is sufficient river run, together with the small storage available, to provide a certain amount of generation throughout the year. The following table gives maximum and minimum produc-

tion, the months in which they occurred, and percentage of minimum to maximum.

	1942	1943	1944	Average
Maximum	153.6 (Sept.)	138.5 (July)	144.9 (May)	145.7
Minimum	55.6 (Feb.)	53.5 (Feb.)	65.9 (Mar.)	58.3
Percent	36.1	38.6	45.5	40.0

The total capacity of these plants represents 5.6 percent of all hydro and 3.7 percent of all generating capacity in Japan. In 1943 these plants generated 3.6 percent of all generation in Japan, 4.4 percent of all hydro generation, and 6.1 percent of all hydro generation of the Japan Electric Generation and Transmission Company.

The generated current is delivered to various transmission lines of the Japan Electric Generation and Transmission Company and was primarily utilized in the Nagoya and Osaka areas.

2. *a.* The Kiso River is one of many streams located in the mountainous regions of central Honshu, lying approximately between 35° 30′ to 36° Lat and 137° to 138° Long. It is about 75 miles in length from source to the location of the last plant. The head, discharge, and relative position of these plants are shown in Exhibit A, and the location of plants, dams, tunnels, etc., is shown in Exhibit B. All of the plants are, in general, of the same type with features common to all hydro plants. Five plants were inspected, namely, Nezame, Momoyama, Yomikaki, Oi, and Kaneyama.

The Nezame plant was completed in September 1938. (Exhibit C, photo 8) Water is obtained by means of a 670 ft aquaduct, a 1600 ft closed channel, and a 39,000 ft tunnel from 3 separate sources, namely, the main Kiso River and 2 tributaries, the Otaka-gawa and the O-gawa. Diversion dams are located at each intake, but these dams do not impound any appreciable storage. The tunnels from the Kiso and Otaka join near the converging point of these 2 rivers, and the one from the O-gawa goes direct to the forebay of the plant. From the forebay, 2 penstocks (Exhibit C, photo 9), each 690 ft in length, lead to the plant. The effective head is 214 ft, and the water quantity is approximately 2,280 cu ft/sec. There are 2 Hitachi, single-wheel, spiral-reaction, vertical-shaft turbines with totally enclosed vertical generators, each rated 20,000-KVA at 80 percent PF. This gives a total of 32,000 KW; however, the plant was rated at 35,000 KW output. Generation is at 50/or 60-cycle so the plant is able to generate for either. Main transformers and switching station are located outdoors a short distance from the plant (Exhibit C, photo 10). The transformer bank consisted of two 20,000-KVA, 3-phase, 11/154-KV, oil-immersed, air-cooled transformers, and the energy is supplied to the main, Kiso, 154-KV, transmission line to Osaka.

The Momoyama plant was completed in November 1923. (Exhibit C, photos 10 and 11). Water from the Kiso is diverted by a concrete diversion dam through a tunnel 1,400 ft in length to a head tank and there by 2 penstocks (Exhibit C, photo 12), each approximately 660 ft long, to the plant. No appreciable water storage is effected by the dam. The effective head is 260 ft, and the water quantity used is 1,300 cu ft/sec. There are 2 Escher Wyss, single-wheel, vertical-shaft turbines with Westinghouse generators, each rated 15,000-KVA at 80 percent PF, and double frequency of 50/or 60-cycles. The total name plate capacity is 24,000 KW, but the plant is rated at 24,600 KW. The main transformer and switching station is located outdoors (Exhibit C, photo 13); the transformers are adjacent to the station, and the switch yard is a short distance away at a higher elevation. There are six 5,000-KVA, 6.6/77 KV, single-phase, oil-immersed, water-cooled transformers and one spare, and the energy is supplied to the 77-KV, Okuwa, transmission line to the Rokugo substation at Nagoya. This station formerly had rotary frequency converter equipment in order that 60-cycle current generated in the hydro plants further down the Kiso River could be changed to 50-cycle in order to supply energy to the 50-cycle section of Japan. This was removed in October 1944 in order to reinstall it in Kyushu where it was greatly needed. According to information received but not verified, the installation in Kyushu has never been completed.

The Yomikaki station was completed in December 1923. Its water supply is from the Kiso. The diversion dam also impounds approximately 11 million cu ft of water. From this dam, there is an open channel 630 ft long, then a closed channel 2,900 ft long, then a tunnel 31,000 ft in length leading to a settling basin and head tank. Three penstocks lead to the plant, each approximately 950 ft long. The effective head is 360 ft, and the water quantity used is 1,600 cu ft/sec. In the plant are 3 Escher Wyss, single-wheel, vertical turbines, each with a Westinghouse, open, vertical-type generator, having a name plate rating of 17,000 KVA at 80 percent PF. This will give a total name plate capacity of 40,800 KW; however, the output obtainable is 42,100 KW. The transformer and switching station is an outdoor type and is located adjacent to the main building. There were 3 banks (of which 1 was spare), each with three

8,500-KVA, 6.6/154-KV, single-phase transformers. Connection is made to the main, Kiso, 154-KV, transmission line to Osaka.

The Oi plant was completed in November 1924 and is the largest plant on the Kiso River (Exhibit C, photo 15). The dam is a concrete, overflow, gravity-type with 21 tainter gates and impounds approximately 250 million cu ft effective water storage, and approximately 400 million cu ft total storage. Water is brought to the plant through a pressure tunnel 1,020 ft in length to a surge tank and thence through 3 concealed penstocks, each 250 ft long. The effective head is 1,400 ft, and the water quantity used is 4,900 cu ft/sec. There are 4 Allis Chalmers, single-wheel, vertical turbines, each with a General Electric generator rated 13,750-KVA at 80 percent PF. This gives a total name plate rating of 44,000 KW; however, the maximum power obtainable is 48,000 KW, and the size of the plant is so rated. Adjacent to the plant, there are 3 banks of transformers, each consisting of three 9,200-KVA, 6.6/154-KV, single-phase transformers, of which one bank is spare. On a higher elevation located nearby is a switching station to which a connection is tapped to the 154-KV, Kiso line to Osaka and also is the starting point of the Kansai, 154-KV line to Osaka via Yao.

The Kaneyama plant was completed in March 1944. (Exhibit C, photo 17) Across the Kiso River is a concrete storage and diversion dam (Exhibit C, photo 16), approximately 600 ft in length, with 14 tainter gates. This dam stores approximately 280 million cu ft of water of which 94 million cu ft are classed as available. From a head race adjacent to this dam, there are 3 concealed steel-lined concrete tunnels or penstocks to the plant. In the plant are 3 Kaplan-type Mitsubishi-make turbines, each with a Mitsubishi generator with a name plate rating of 15,500 KVA at 80 percent PF. The total name plate rating of the plant is 37,200 KW; however, the rating given on the records is 37,100 KW. Adjacent to the plant is an outdoor transformer and switching station (Exhibit C, photo 18). There are three 15,500 KVA 3-phase 11/154-KV transformers and a tap to the Kansai transmission line to the Yao substation near Osaka.

Complete engineering data on the plants inspected are in USSBS files. The plants in this hydro area which were not visited are, in substance, the same type of plant. In addition to the plants listed, there is one plant under construction, named Agematsu, located between the Nezame and the Momoyama plants. It was to be 8,000 KW in capacity with a head of approximately 70 ft. Construction was started in 1943 and was well along but was never completed because cement was not obtainable. In the construction work about 300 Chinese coolie prisoners of war were used.

Exhibit C, photos 3 and 4 show the Ontake plant. Photos 5 and 6 show the Tokiwa plant, and photo 14 shows the Suhara plant.

b. The source of power is the Kiso River watershed. The plants are typical run-of-river type, and dams are principally used for diversion. However, there is some reservoir storage, especially at the Miura plant (Exhibit C, photos 1 and 2) which is at the head waters, and thus the flow can be governed and utilized to the best advantage by all the plants. Therefore, while maximum generation is during the wet season, the plants are in a position to generate considerable energy throughout the entire year. The table below gives the effective storage in cu ft and KWH based on allowable low water levels as set by the Power Bureau and other departments involved such as Agriculture and Forestry. There is considerably more storage available, and, during the war, water levels in the reservoirs were, on a number of occasions, drawn far below the effective levels. The storage in KWH is based on that obtainable by all plants below the reservoir:

Plant	Effective cu. ft.	Storage in KWH
Miura	1,851,000,000	104,100,000
Tokiwa	20,000,000	52,800
Ochiai	31,000,000	200,000
Oi	254,000,000	1,160,000
Kasagi	181,000,000	345,600
Kaneyama	109,000,000	137,000
Totals	2,446,000,000	105,995,400

3. The plants are owned by the Japan Electric Generation and Transmission Company. Information was obtained from:

Mr. S. Saito —Director and district mgr. of the Tokai district, Japan Electric Generation and Transmission Company, in which these plants are located.
Mr. G. Kato —Chf. engr. Nezame Plant
Mr. T. Okobo —Chf. engr. Momoyama Plant
Mr. C. Iimura —Chf. engr. Yomikaki Plant
Mr. S. Inubuse—Chf. engr. Oi Plant
Mr. K. Kato —Chf. engr. Kaneyama Plant

4. The Nezame plant normally uses 25 employees, Momoyama 23, Yomikaki 33, Oi 35, and Kaneyama 30. The total for all the plants on this river is approx-

imately 300. They work two shifts and are used continuously throughout the year.

Attacks.

None of the Kiso River hydro plants was ever subject to attack and there was no damage from any type of war action.

Effects of Bombing.

1. Physical damage.

Since there was no damage, no study of bombing effects could be made.

2. Production loss.

There was no production loss.

3. Recuperability cycle.

No damage occurred and therefore no recuperability could be determined. However, since these hydro plants, like most of the hydro plants in Japan, are located in very remote and inaccessible places, the recuperability time would be considerably longer than normal.

4. Vulnerability.

Hydro plants are vulnerable from the standpoint of their susceptibility to bomb damage, and, in particular, damage could be done to penstocks or outdoor switching and transformer stations that would render the plants inoperative for a long period. However, they are generally located in inaccessible places in very mountainous country and would have to be bombed from a high level. The small size of the buildings and the great number of the plants would make effective bombing very difficult. Therefore, the vulnerable points for this, as well as other hydro groups, are at the substations which collect and redistribute their generated current.

Intelligence Check.

1. *a.* OSS reports in general correctly identified and evaluated these plants with the following exceptions:

The Kaneyama Plant shown as completed and in use in 1939. The plant actually started operating the first unit in August 1943 and the plant was completed in March 1944.

Tokiwa, shown as completed in 1939, was actually completed in 1941.

The Miura and the Ontake plants were not listed since they were both new plants, however, the Miura Dam and plant are shown on Map No 2455.

b. The Air Objective Folder No 90.16 lists the following plants and assigns target numbers:

*Otaki	1498
Momoyama	1499
Yomikaki	1502
Oi	1505
Kasagi	1615

*This is evidently the Nezame plant incorrectly named.

There is no explainable reason why some of the less important ones are listed and larger ones omitted.

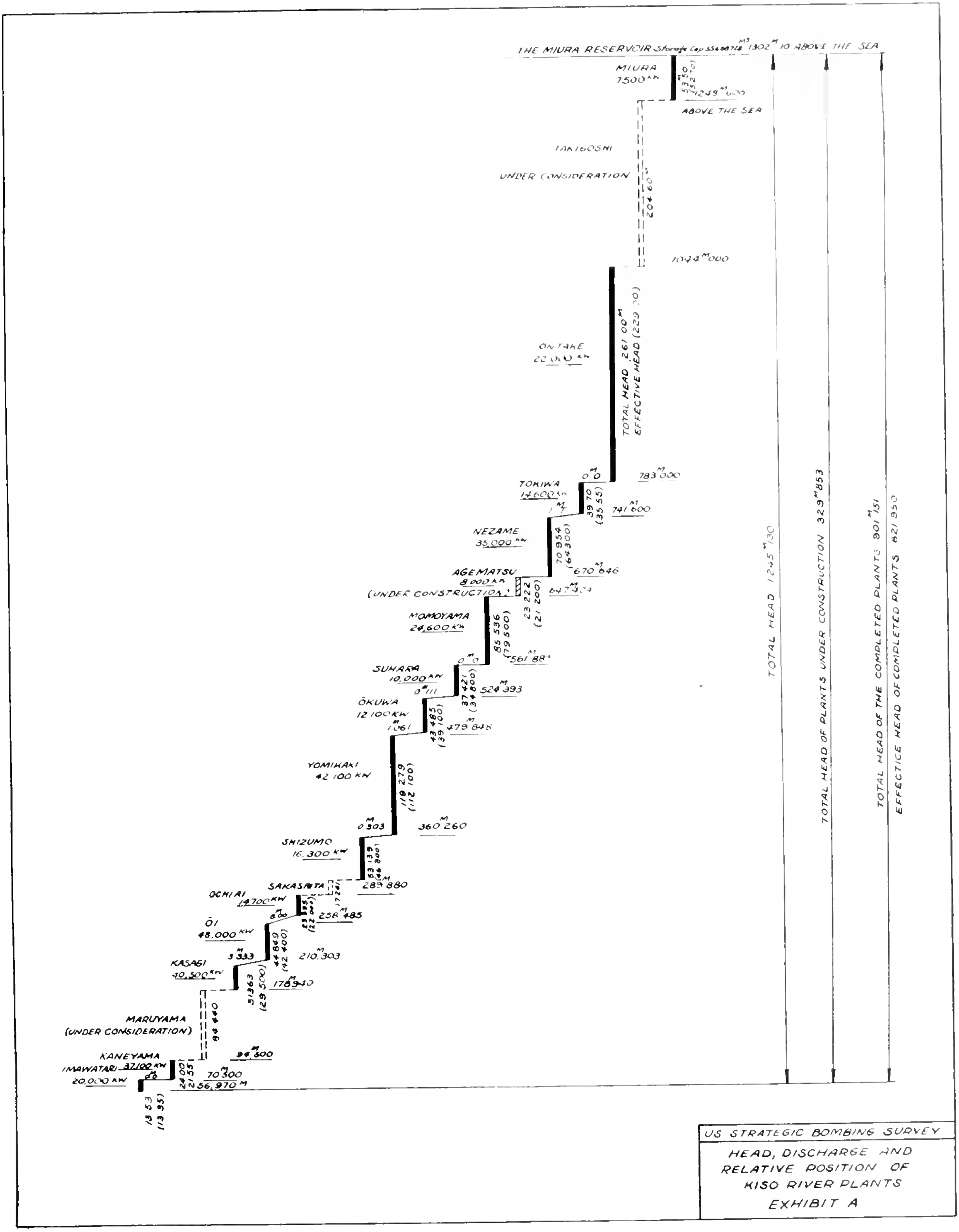
c. JTG lists the same plants as the Air Objective Folder and gives brief descriptions.

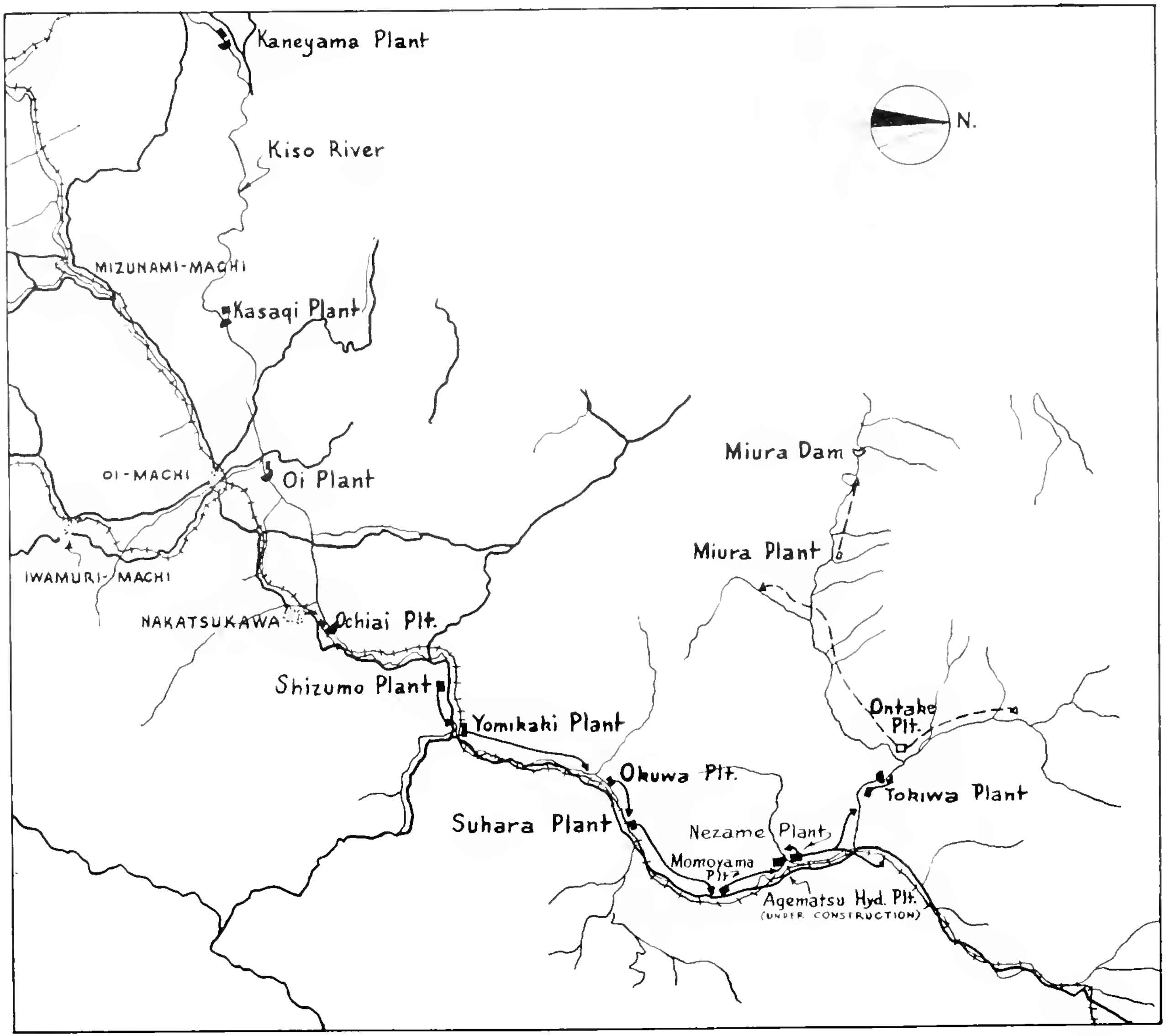
Data Relevant To Other Studies.

None.

Evaluations and Impressions.

These plants are modern and maintenance is good. The natural resources of this river have been developed in an excellent manner. The Electric Power Bureau, with the other interested bureaus such as Agriculture and Forestry, had set limitations on the low water point on the storage reservoirs, in order to insure a constant water supply for other purposes. During the war, however, the electric energy requirements were such that exceptions were made and water was utilized far below this minimum on several occasions. Chinese coolie prisoners of war were used in the construction of a new plant which was never completed because of the lack of cement.


THE MIURA RESERVOIR 1302 M 10 ABOVE THE SEA
MIURA
7500 KW
1249 M 600
ABOVE THE SEA
TAKIGOSHI
UNDER CONSIDERATION
204.60 M
1044 M 000
ONTAKE
22,000 KW
TOTAL HEAD 261.00 M
EFFECTIVE HEAD (229.00)
783 M 000
TOKIWA
14,600 KW
39.70
(35.55)
741 M 600
NEZAME
35,000 KW
70.954
(64.300)
670 M 646
AGEMATSU
8,000 KW
(UNDER CONSTRUCTION)
23.222
(21.200)
MOMOYAMA
24,600 KW
85.536
(79.500)
561 M 88
SUHARA
10,000 KW
37.421
(34.800)
524 M 393
ŌKUWA
12,100 KW
43.485
(39.100)
479 M 848
YOMIKAKI
42,100 KW
119.279
(112.100)
0 M 303
360 M 260
SHIZUMO
16,300 KW
53.139
(46.800)
289 M 880
SAKASHITA
OCHIAI
14,700 KW
258 M 485
ŌI
48,000 KW
3 M 333
44.849
(42.400)
210 M 303
KASAGI
40,500 KW
31.363
(29.500)
MARUYAMA
(UNDER CONSIDERATION)
94.440
94 M 600
KANEYAMA
37,100 KW
IMAWATARI
20,000 KW
24.00
21.55
70 M 300
56,970 M
13.53
(13.35)
TOTAL HEAD 1245 M 130
TOTAL HEAD OF PLANTS UNDER CONSTRUCTION 329 M 853
TOTAL HEAD OF THE COMPLETED PLANTS 901 M 151
EFFECTIVE HEAD OF COMPLETED PLANTS 821.950
US STRATEGIC BOMBING SURVEY
HEAD, DISCHARGE AND RELATIVE POSITION OF KISO RIVER PLANTS
EXHIBIT A



U.S. STRATEGIC BOMB SURVEY

LOCATION PLAN OF KISO RIVER PLANTS

EXHIBIT-B

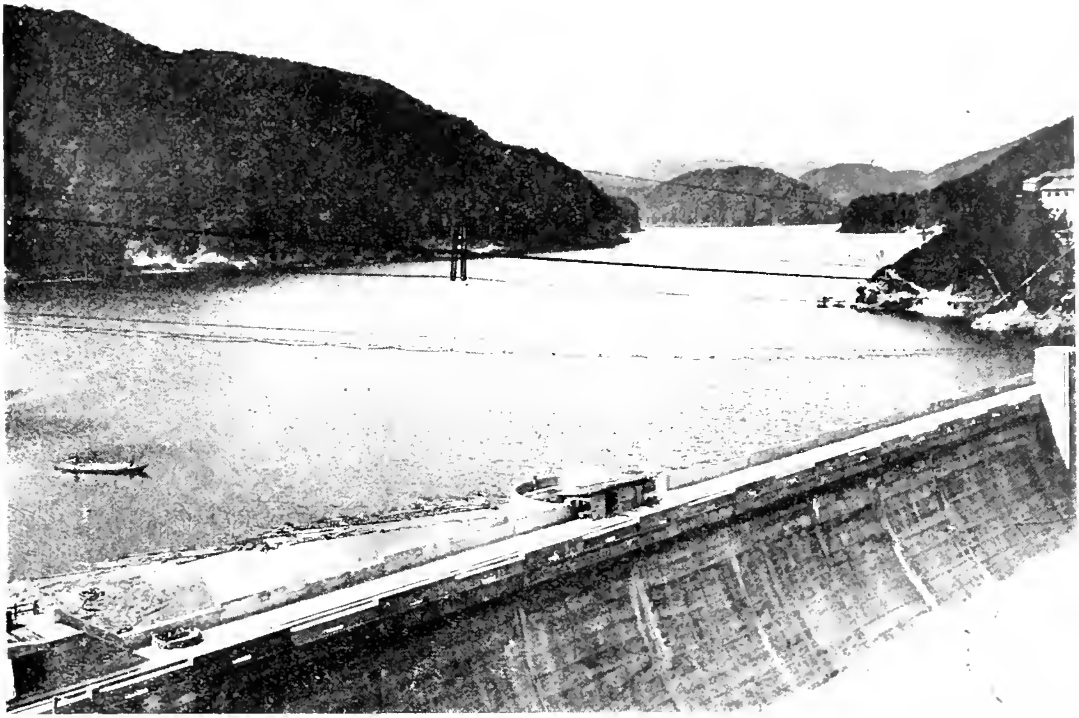


Photo 1—Miura Dam

Photo 2—View of Miura Dam from reservoir

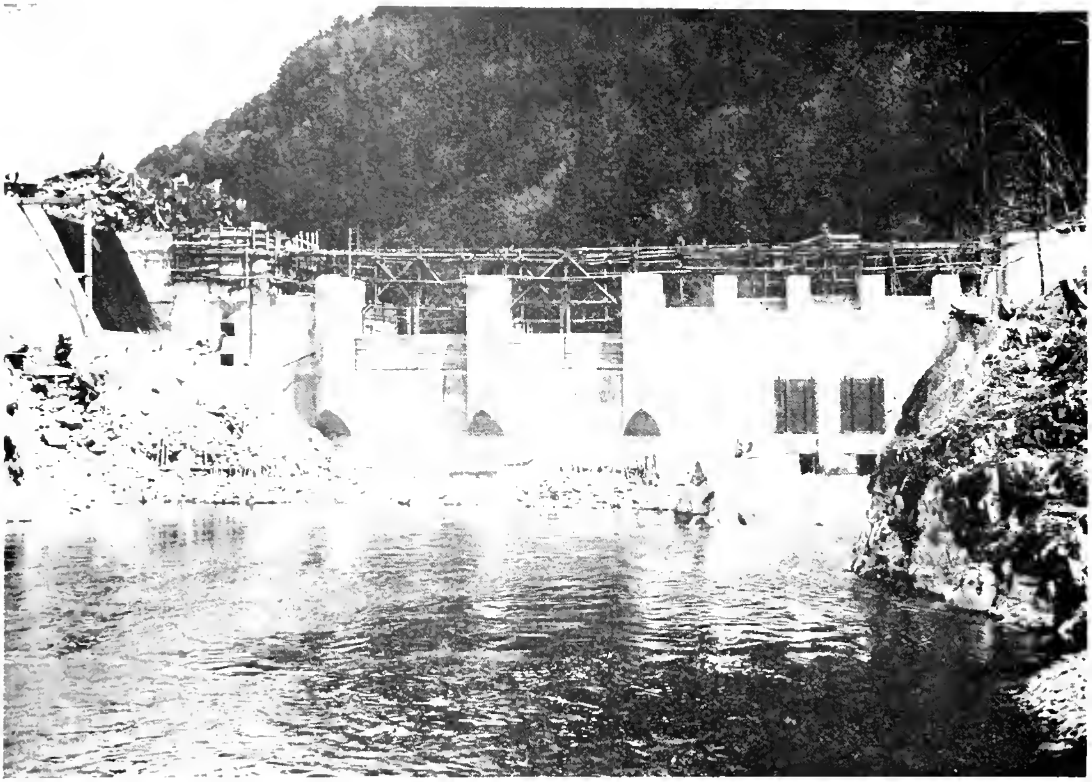


Photo 3—Ontake Diversion Dam (during construction)

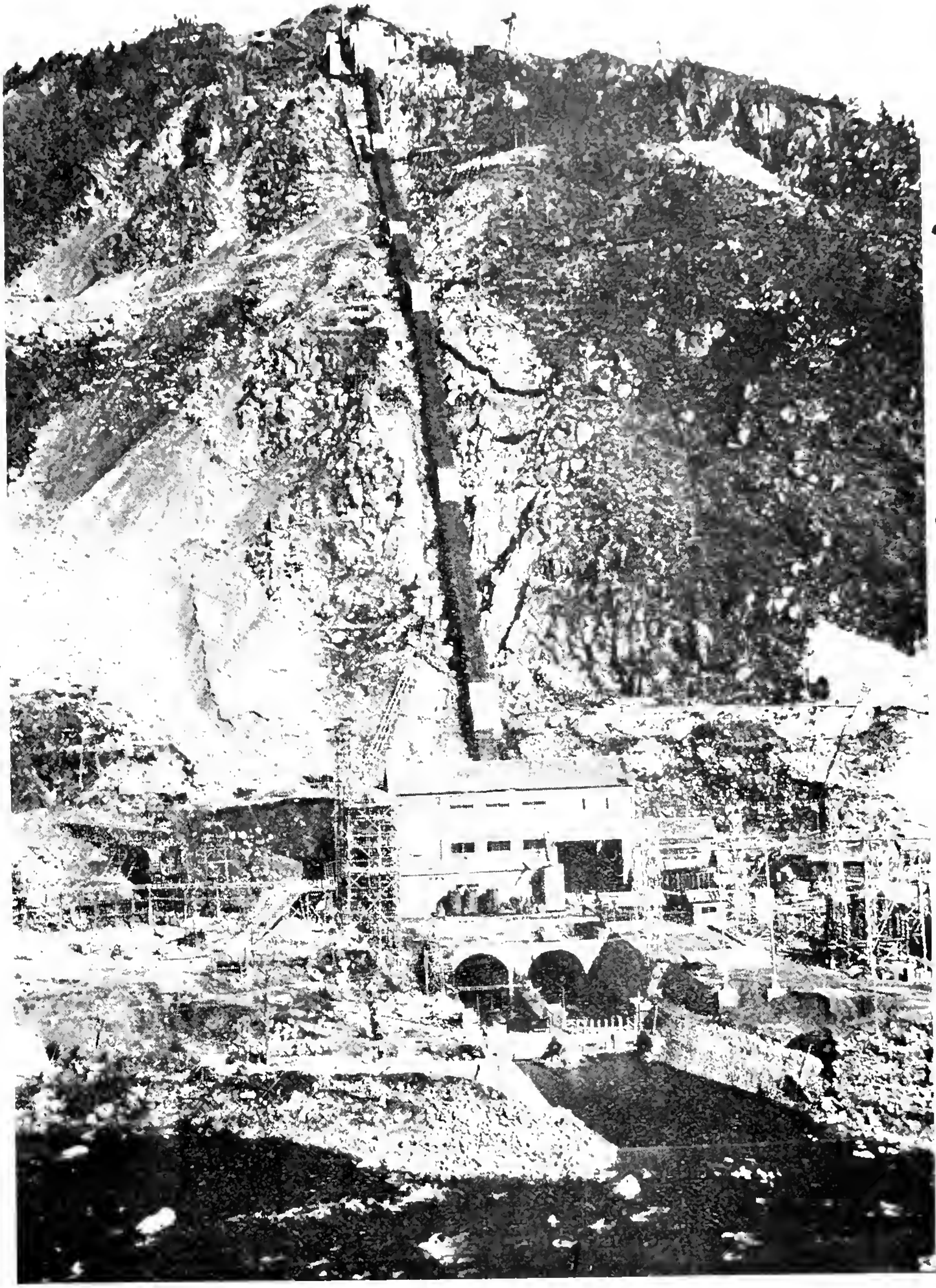


Photo 4—Ontake Power Plant, Penstock & Headtank

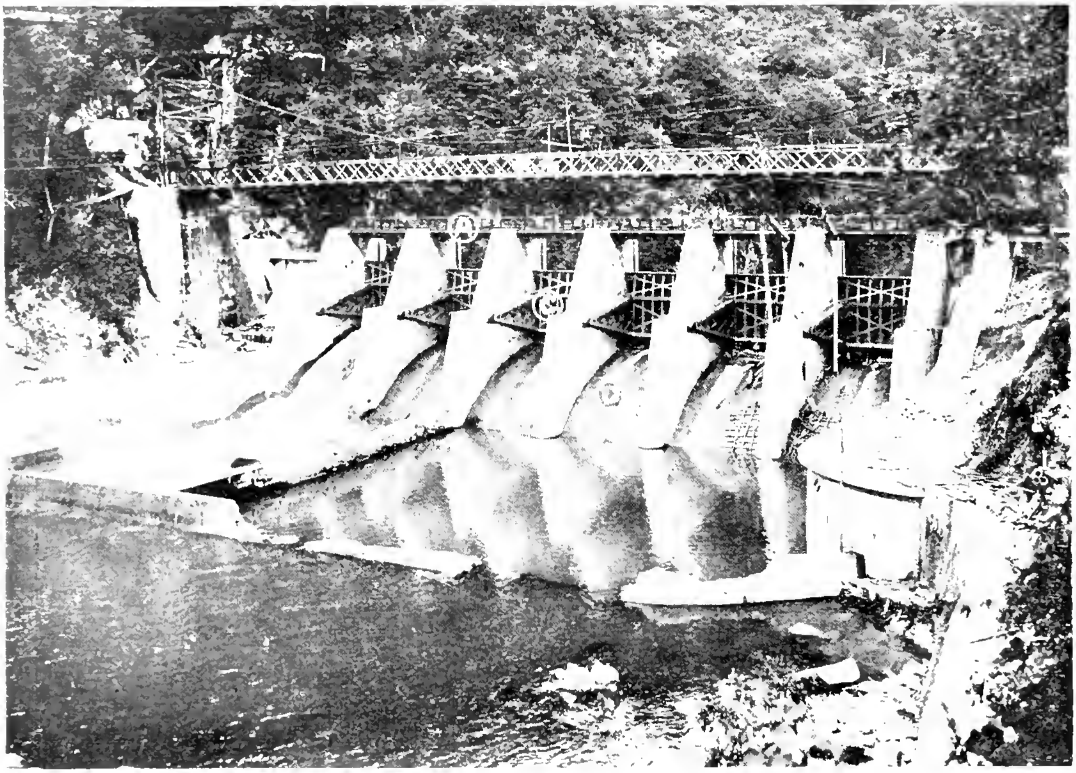


Photo 5—Tokiwa Diversion Dam

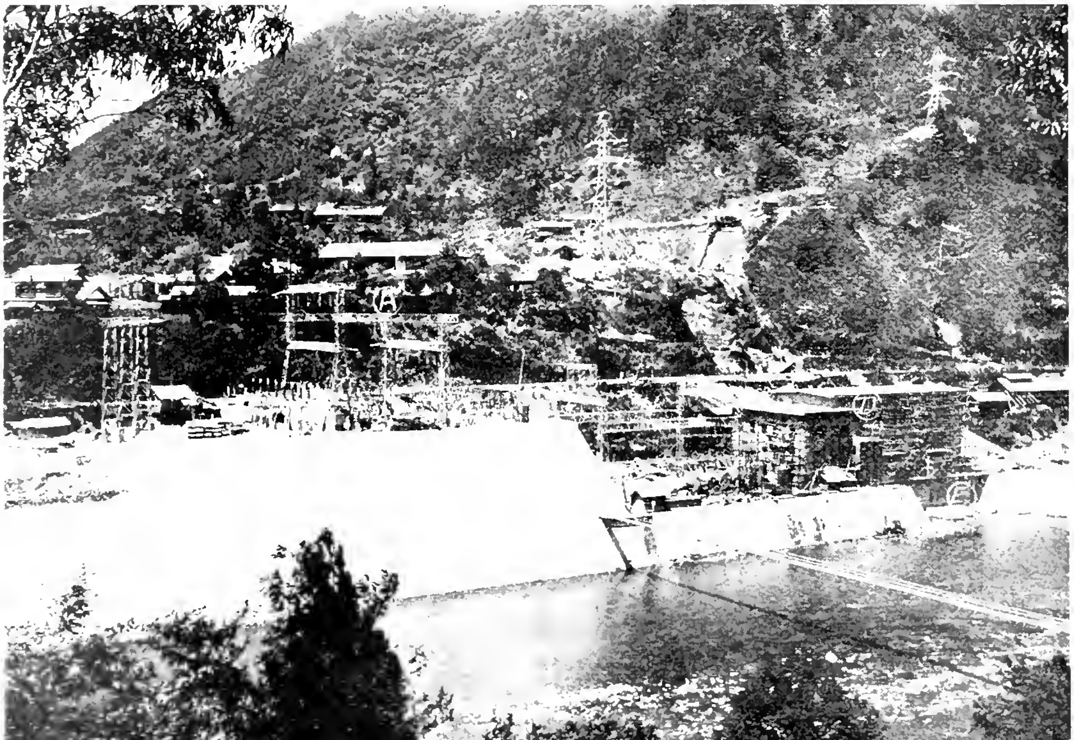


Photo 6—Tokiwa Power Plant (during construction)

Photo 7—Nezame Power Plant—General view

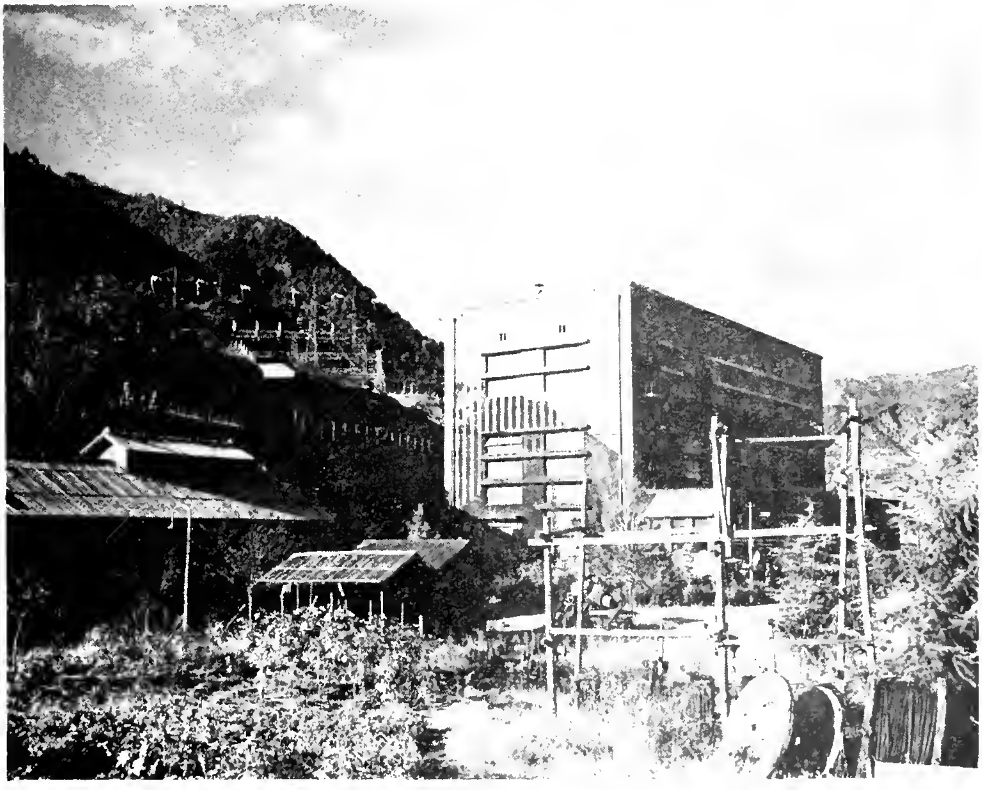


Photo 8—Nezame Power Plant—Switch yard at left

Photo 9—Nezame Power Plant Penstocks

Photo 10—Momoyama Power Plant—General view

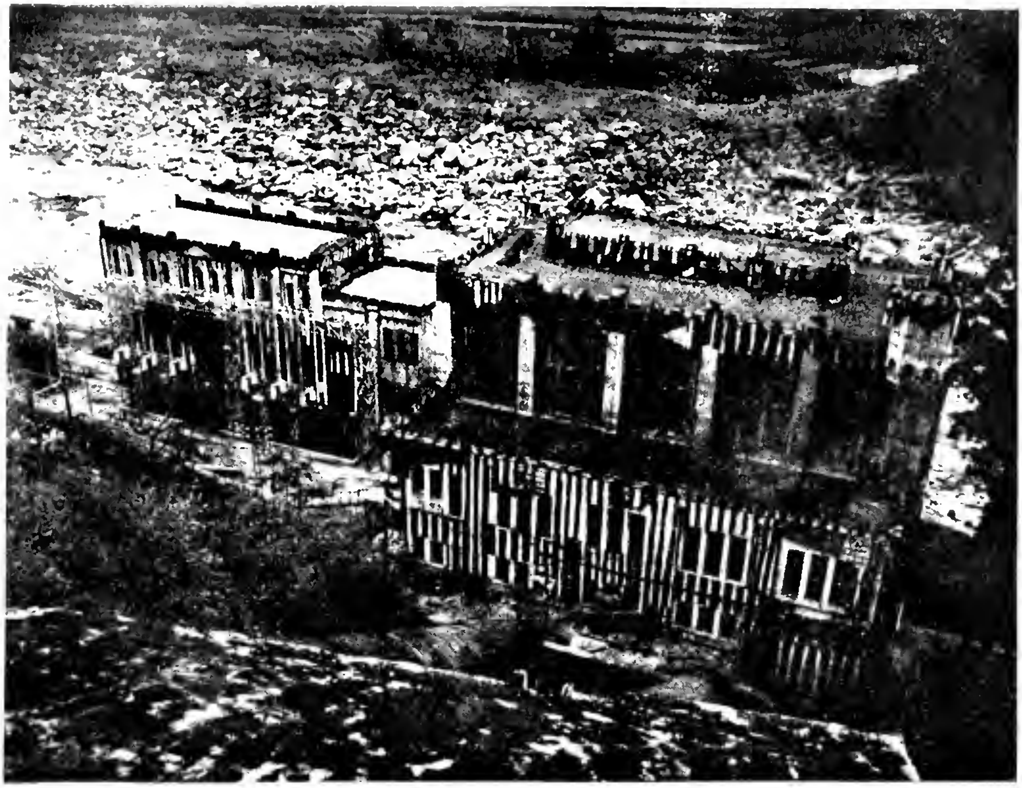


Photo 11—Momoyama Power Plant general view from penstocks

Photo 12—Momoyama power plant penstocks

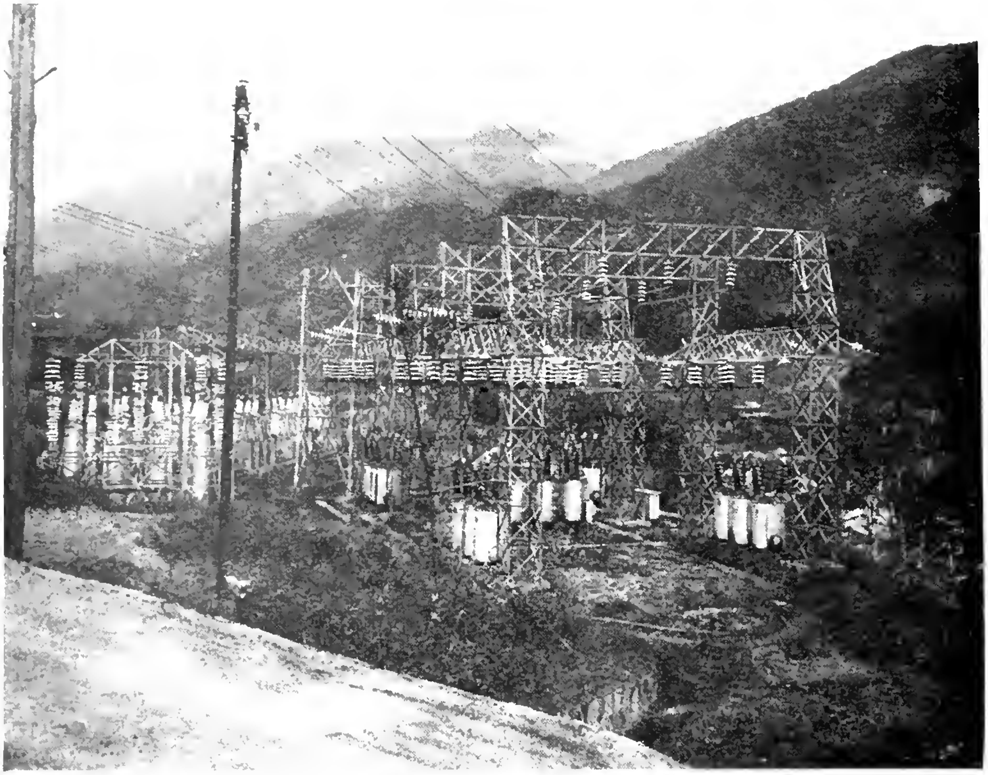


Photo 13—Momoyama power plant switch yard

Photo 14—Suhara power plant—general view

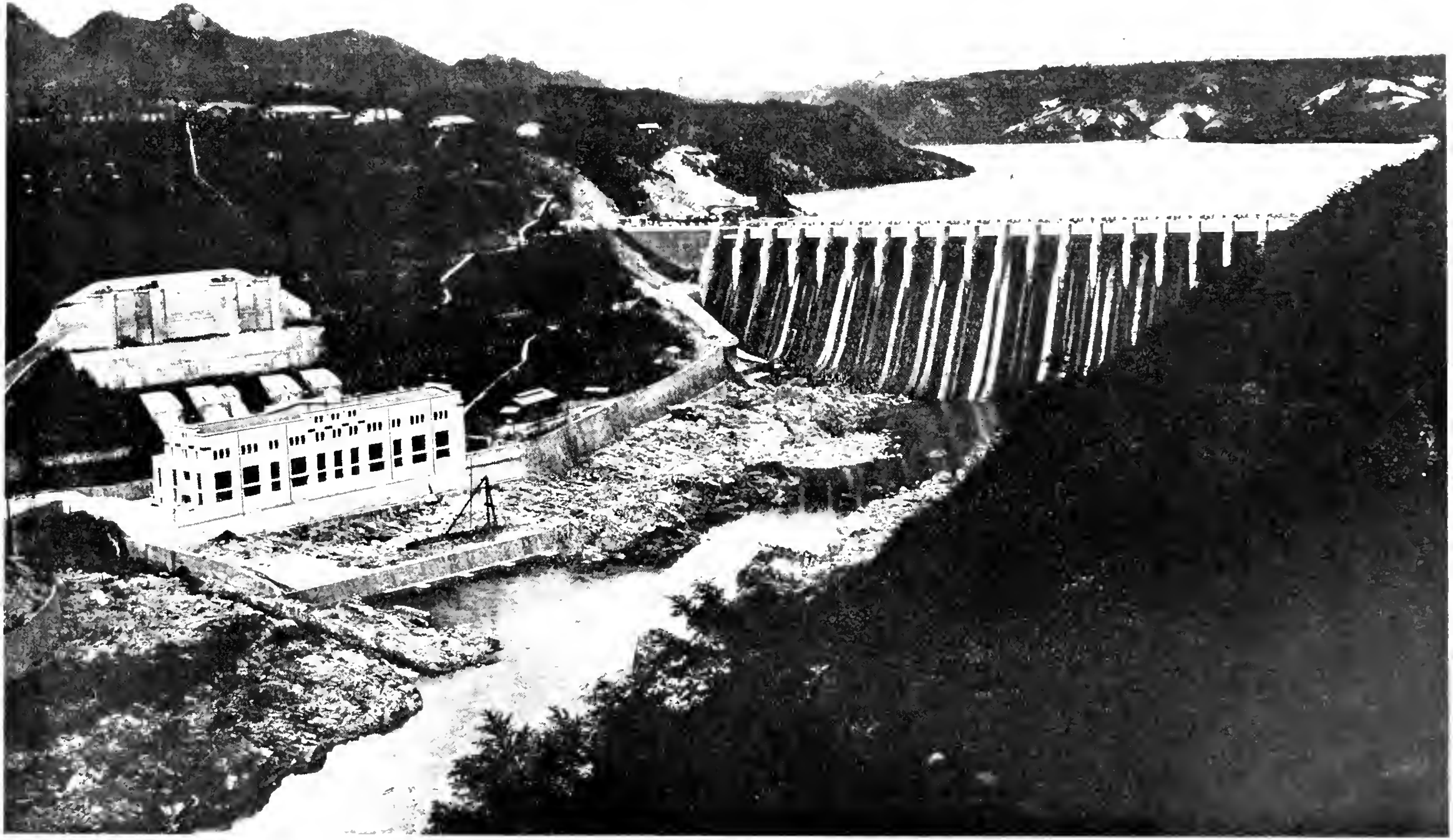


Photo 15—Oi power plant, general view

Photo 16—Kaneyama power plant diversion and storage dam

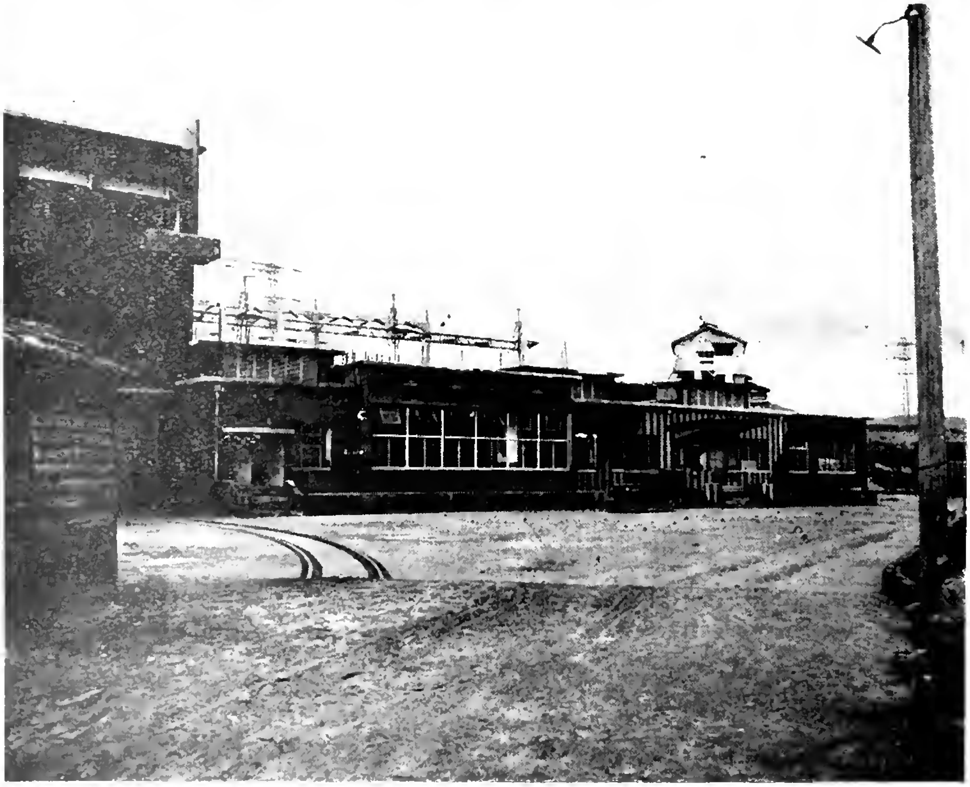


Photo 17—Kaneyama power plant entrance

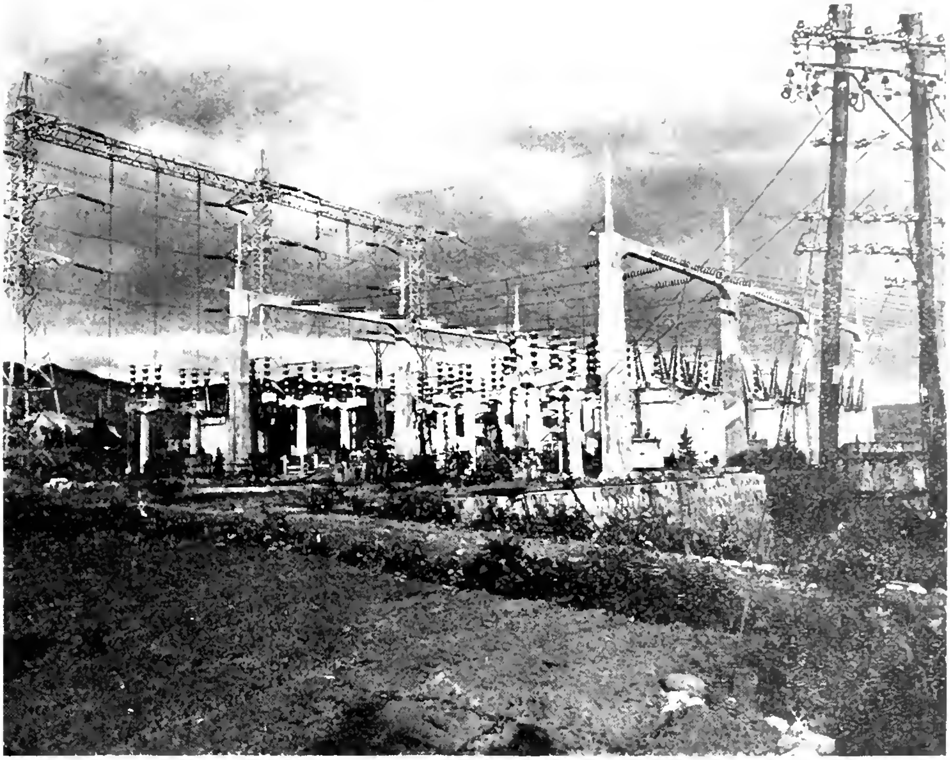


Photo 18—Kaneyama power plant transformer and switching station

PLANT REPORT NUMBER 16

SAKU HYDRO ELECTRIC STATION

TONE RIVER, NEAR SHIBUKAWA, JAPAN

DATE INSPECTED 15 NOVEMBER 1945

Summary.

1. The Saku Hydro-electric Station, located on the Tone River opposite from the Town of Shibukawa, is the largest hydro station in the Tokyo plain area and had on 15 November 1945, 67,200 KW of name plate capacity, but is rated by official records at 72,700 KW capacity. The plant is divided into 2 sections. One section consists of a 7.6 mile intake tunnel, a small forebay, a pressure tunnel, a surge tank, and 3 steel penstocks bringing water from a diversion dam on the Tone River. The second section secures its water supply from the Agatsuma River through 2 miles of tunnel and covered canal, a concrete surge tank, and a steel penstock to the north end of the power house. The power house is a peaked roof, concrete building with a steel switch yard to the north. The second section is not in service because of the removal of the generator for a projected plant in Kyushu. The plant generated approximately 390 million KWH per year during the 3 war years. While its output was seasonal, there was sufficient river run to operate continuously throughout the year, and its minimum dry season month generation was 52.7 percent of its maximum wet season month generation. The energy was delivered to the transmission lines of the Japan Electric Generation and Transmission Company for general distribution, and most of it was utilized in the Tokyo area.

2. The plant was never a primary target, but was damaged on 30 July 1945 by carrier-based Navy planes unable to reach their planned objective. One 250 lb fragmentation bomb hit near the turbine room, damaging one generator and destroying a regional load dispatcher's office building, and 50-cal strafing punctured in several places the surge tank above the penstocks.

3. The principal physical damage was physical injury to the stator windings of one 28,000-KVA generator which was not operating at the time of the raid. No repairs have been started, although spare coils and facilities are available. While production was down at the time of damage, because of loss of demand through industry or city destruction, the loss of production from the damage to the plant, based on average production during the 3 war years, amounted to approximately 38 million KWH. This loss is on the basis of the ability to restore production. Recuperation ability was, in this case, greater than average, since materials and facilities were available. Had damage been very slightly greater, recuperation would have taken far longer. This plant was more vulnerable than the average hydro plant, since it was in an open valley and easily identifiable.

4. The size, importance, and location had been correctly evaluated in intelligence data, and the single hit correctly reported. Damage was not assessed nor could such assessment be made from the air.

5. While the damage caused no large production loss, it is significant that serious damage was done by a single bomb and that power plants were proved to be susceptible to great damage from strafing.

The Plant and Its Function In Enemy Economy.

1. The product of the plant and its importance in enemy economy.

The Saku plant, one of nearly 400 in the hydro system of the Japan Electric Generation and Transmission Company, was the largest in the Tokyo plain 50-cycle area; eleventh in capacity importance in the company; and produced approximately 1.1 percent of the utility energy used in Japan. Its monthly generation is recorded in Exhibit B for the years 1942 to July 1945, and averaged 390,000,000 KWH per year for the 3 war years. The maximum load carried was 72,700 KW with 4 units operating and 66,000 KW after one small unit was removed. At the time of inspection, a total of 36,000 KW was being carried on the 2 operable units. Load curves for the war period are shown in Exhibit A, which also shows the potential generation based on available water power. This shows that almost all available power was being utilized until March 1945, at which time the demand became greatly reduced because of the destruction of industries and cities or the loss of industrial usage during dispersal. The output was supplied to the Japan Electric Generation and Transmission Company for general distribution, and most of it was utilized in the Tokyo area.

2. *a.* The plant is located on the east bank of the Tone River opposite the town of Shibukawa. The main building is a 3-story, peak roof, reinforced con-

crete, rectangular building, approximately 75 ft by 200 ft, which houses all turbo-generators, equipment, and controls. Adjacent to one end of the building, and at a slightly higher elevation, is located an outdoor transformer and switching station. Although the entire plant is together, it was constructed in 2 sections. The first section was completed in 1928 and consists of a dam on the Tone River, 7.6 miles of intake tunnel, a forebay regulating reservoir, an underground steel pressure conduit approximately 500 ft in length, a steel surge tank mounted on a steel tower with an overall height of approximately 250 ft, and 3 steel penstocks leading from the surge tank to the turbines. The effective head is approximately 375 ft and the maximum flow is 2065 cu ft/sec. There are 3 Allis Chalmers, Francis-type, vertical turbines, each with a Westinghouse 28,000-KVA, 3-phase, 50-cycle, 11 KV generator. The second section was completed in 1938. The water is from the Agatsuma River, diverted by a dam through 2 miles of intake tunnel and covered canal to a forebay and through one penstock to the plant. Effective head is 80 ft and maximum water flow is 1169 cu ft/sec. There is one Hitachi, propeller-type, vertical turbine which was previously connected to a Hitachi, 7500 KVA, 90 percent PF, 3-phase, 11 KV, 50-cycle generator. This generator has been removed for transfer to another plant. The total name plate capacity of this plant was, prior to removal of this unit, 73,950 KW and is at present 67,200 KW. The Japanese carry its official licensed capacity at 72,700 KW, and have not changed the records since the removal of the one unit. The outdoor switch and transformer station contains 9 Tokyo Shibaura 9,333-KVA, single-phase, transformers in 3 banks, transforming from 11 to 154 KV. Exhibit C shows photographs of the plant, penstocks, and substation.

b. The water supply is from the Tone and Agatsuma Rivers. The Tone River, above the dam, has a water shed of 680 square miles, and the Agatsuma River above the dam has a water shed of 500 square miles. The rainfall is approximately 30 inches per year at the Tone intake, 900 ft above sea level. The river flow is at a minimum in February and reaches maximum during March, April, and May. Exhibit A shows variation in plant output due to river flow.

3. The plant is owned by the Japan Electric Generation and Transmission Company. Information was furnished by the following:

Sho Nishikawa, Chief, Gumma District
Kazuo Hase, Chief, Electric Power Section, Gumma District
Sadakichi Yomaguchi, Station Master, all of Japan Electric Generation and Transmission Co.

4. There are normally 60 employees. This number did not fluctuate during the war period.

Attacks.

The plant was attacked by a flight of 7 or 8 carrier-based planes at 0700, 30 July 1945, flying from a southerly direction at low altitude. This has been identified as strike "Dog Two", 30 July, of Carrier USS Randolph, CV-15, stationed at the time about 140 miles south of Nagoya.

Effects of Bombing.

1. Physical damage.

One 250 lb HE fragmentation bomb struck a stone wall 20 ft from the south corner of the power house. Fragments and flying debris broke the windows on the SE end of the power house, and one fragment cut through the sheet metal casing of one 28,000-KVA generator, damaging the stator windings. The machine was not operating at the time. This same bomb demolished a frame building housing the district load dispatcher's office, located about 35 ft from the point of explosion. The surge tank was strafed by 50-cal machine gun fire, and punctured in several places.

2. Production loss.

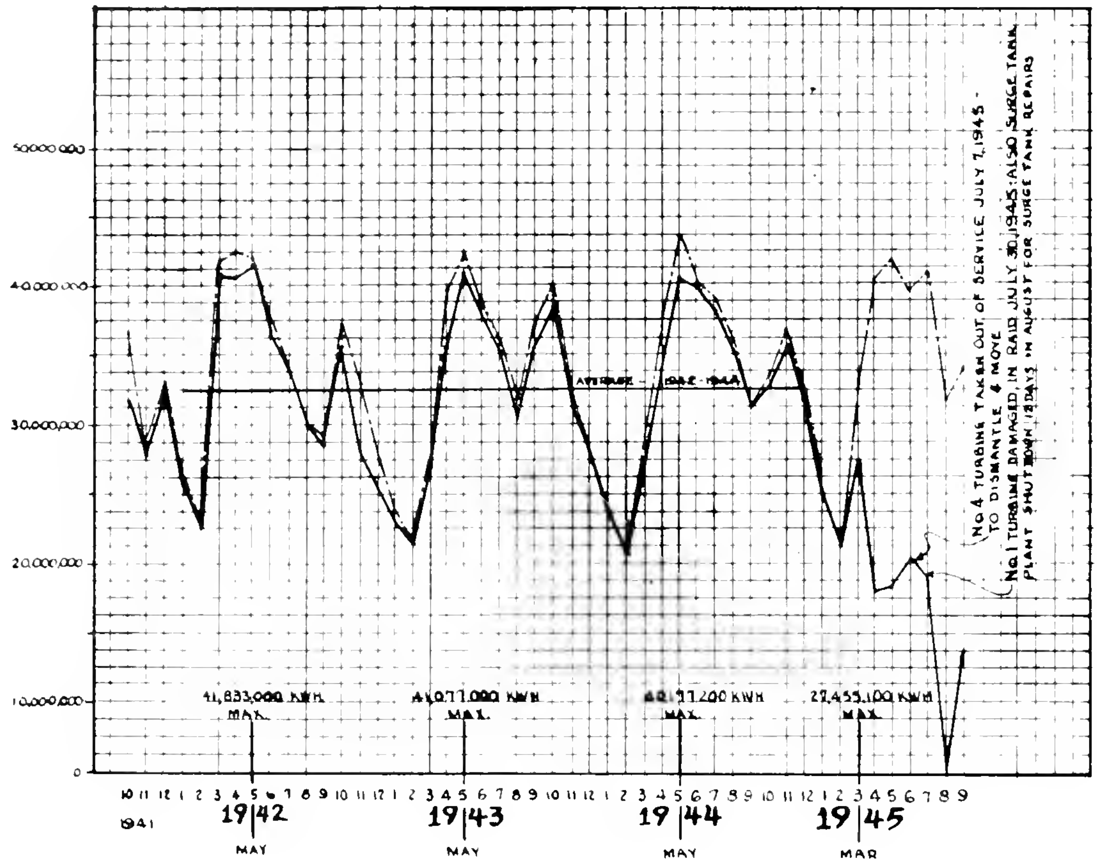
Coincidental with the bombing, the small generator was being dismantled for transfer to another plant, and so production records reflect its removal as well as bomb damage; also, production was down because of the loss of load from destruction of industries and cities. The entire plant was out of service for 12 days while bullet holes in the surge tank were being welded. The damaged generator has not been repaired. Therefore, the production loss is based on average production during the 3 war years, on the basis of the entire plant production for the time to repair the surge tank, and one-third of plant production for 2 months, because of the loss of one large generator and time estimated to place it back in service. This estimated loss equalled 38 million KWH.

3. Recuperability.

The plant was put back into operation after 12 days for repairs to the surge tank. The damaged generator, for which spare coils are on hand, could have been restored to service in approximately 2 months, although no start has been made on its repair.

4. Vulnerability.

This plant, like all power plants, is vulnerable to bomb damage. No hits on important equipment were made, and the one bomb was light, with the strike



——— Actual Generation

—·— Potential Generation

LOAD CURVE
SAKU HYDRO-POWER PLANT

EXHIBIT A

point outside the plant. Therefore no conclusions can be drawn regarding the effect of a hit on vital equipment. The strafing of the surge tank produced no substantial damage. Better targets would have been the main transformers or the machinery inside the power house windows.

Intelligence Check.

1. *a.* The OSS Report correctly evaluated the plant as of date of preparation.

b. The Air Objective Folder No 90.13 for Takasaki Area, issued by the Assistant Chief of Air Staff, Intelligence, listed this plant as Target No 1,059, correctly located it on maps, described it adequately, evaluated its importance correctly, and presented a good photograph of the plant prior to the extension to the northwest.

2. Record of this raid, as reported in the USS Randolph action report for the period of 1 July to 15 August 1945, reported 1 direct bomb hit on the plant, but did not mention strafing. Sixteen VF and 15 VB took part in the strike over the area. No photos were taken during or after the raid, and no evaluation of damage was reported.

Evaluations and Impressions.

The Saku Plant, one of the best in the system of the Japan Electric Generation and Transmission Co., is well built and maintained. The supervisors and operators showed intelligence and knowledge superior to that of operators in other plants visited, had a pride in their property and work, and appeared capable of handling their responsibilities.

Exhibit B

Saku Hydro Power Plant

Generation in KWH

	1942	1943	1944	1945
Jan	26, 111, 000	23, 237, 500	23, 797, 000	24, 843, 800
Feb	22, 550, 000	21, 301, 200	20, 834, 100	21, 208, 000
Mar	40, 885, 000	27, 021, 000	27, 533, 000	27, 455, 100
Apr	40, 797, 000	36, 079, 100	34, 034, 400	17, 883, 400
May	41, 833, 000	41, 077, 000	40, 177, 200	18, 235, 100
June	36, 675, 800	38, 625, 700	39, 719, 100	20, 183, 200
July	33, 679, 300	35, 341, 200	38, 406, 000	18, 574, 700
Aug	29, 991, 000	30, 236, 900	35, 239, 400	
Sept	28, 599, 200	35, 581, 100	31, 182, 100	
Oct	35, 461, 000	38, 854, 000	32, 771, 500	
Nov	28, 525, 300	31, 316, 400	34, 996, 100	
Dec	28, 146, 000	28, 085, 000	31, 770, 100	
Total	393, 253, 600	386, 756, 100	390, 460, 000	148, 383, 300

Relation of Minimum to Maximum Monthly Production

Expressed in million KWH

	1942	1943	1944	Average
Maximum	41. 8 (Mar.)	41. 1 (May)	40. 2 (May)	41. 0
Minimum	22. 6 (Feb.)	21. 3 (Feb.)	20. 8 (Feb.)	21. 6
Percent	54. 1	51. 8	51. 7	52. 7

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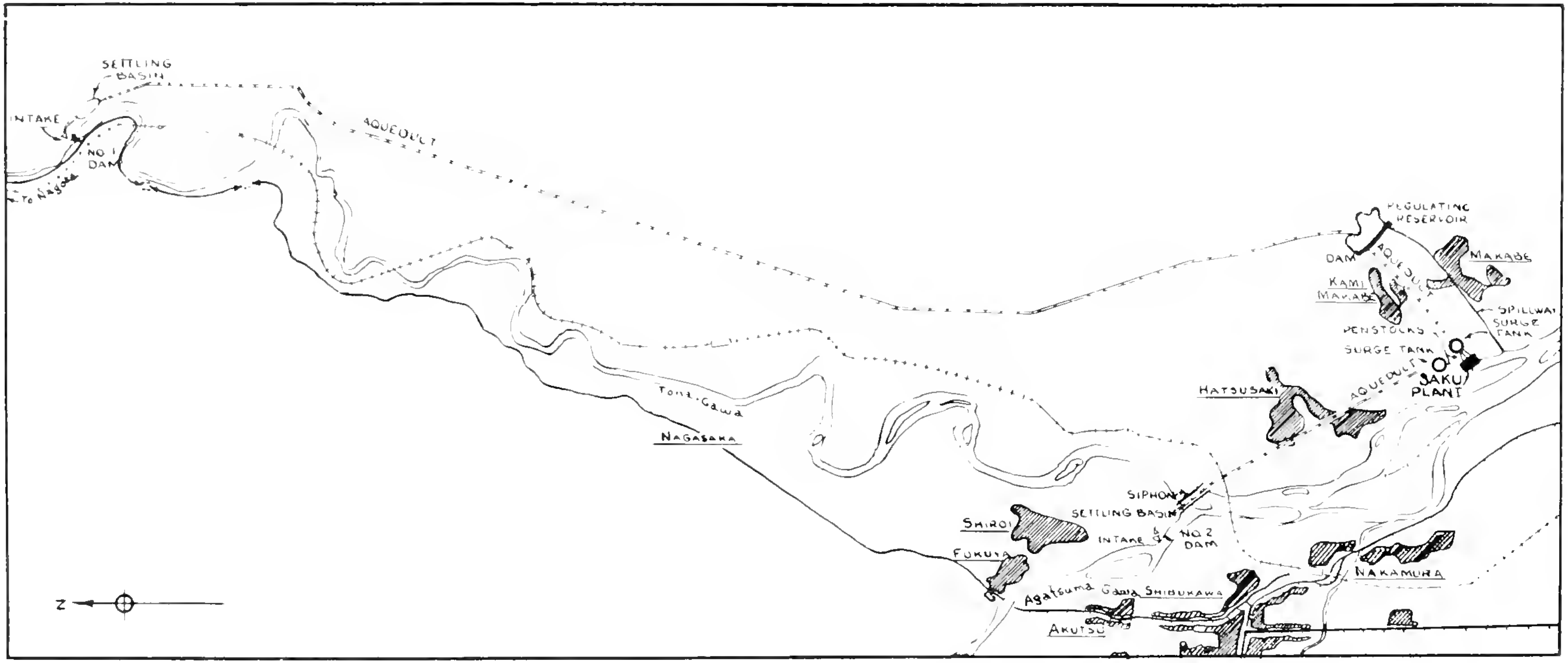

SAKU HYDROELECTRIC PLANT

EXHIBIT "C"

Photo 1—Tone River below Saku plant

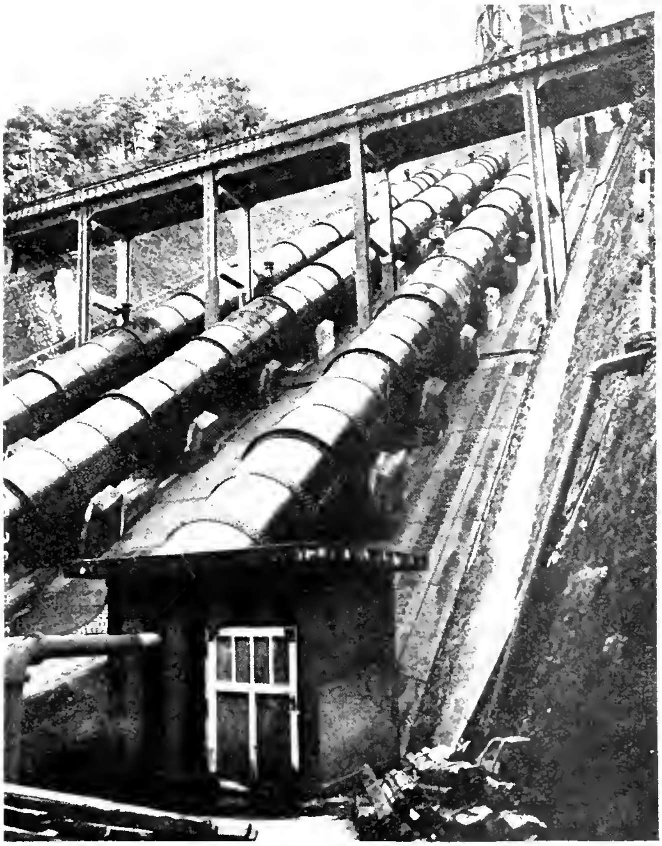

Photo 2—Penstocks and bridge

Photo 3—Transformer bank

Photo 4—Bomb fragment holes in generator housing

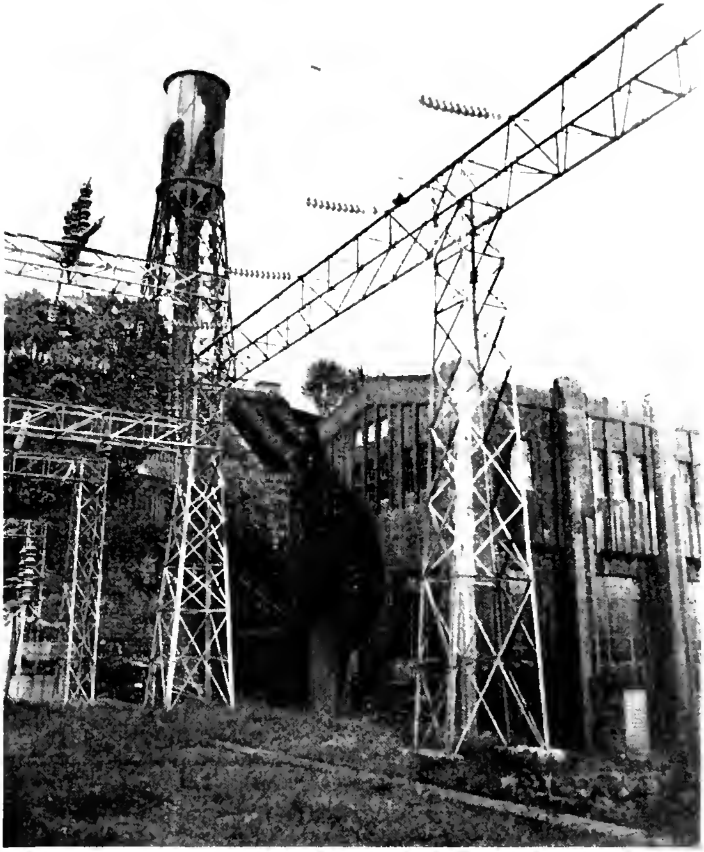

Photo 5—General view from switchyard

Photo 6—Tank (damaged by strafing) and penstocks

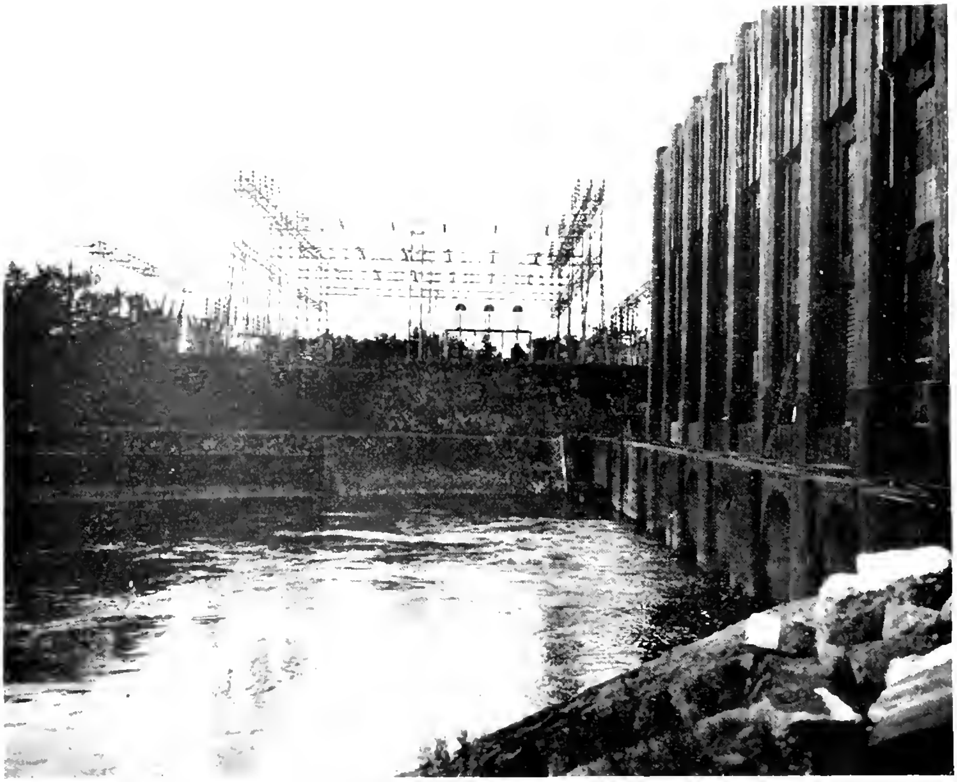

Photo 7—General view of plant, tail race, and switchyard

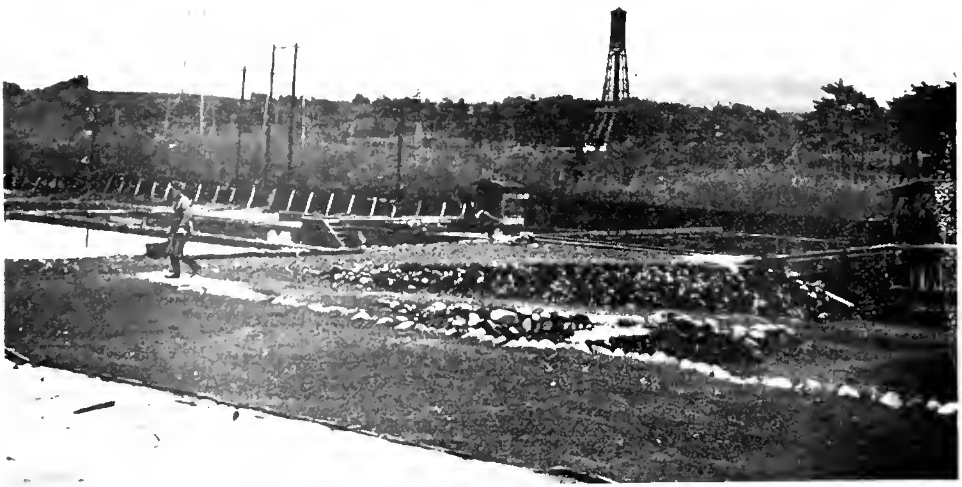

Photo 8—General view from factory across river

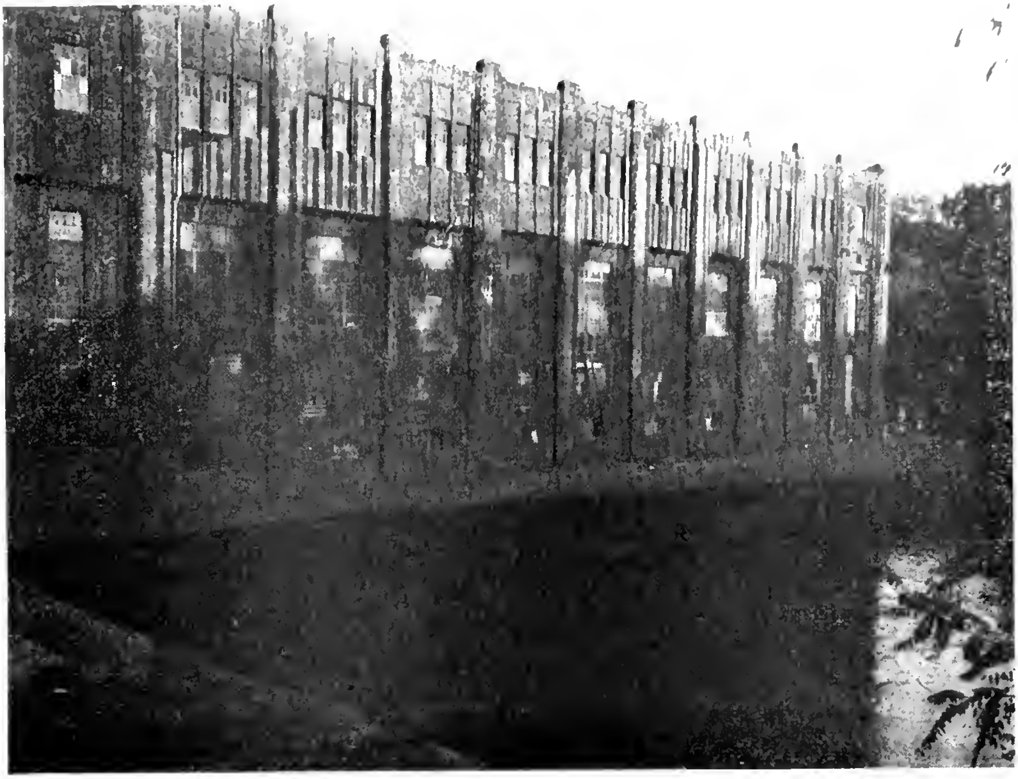

Photo 9—General view of plant and tail race from switchyard

Photo 10—Penstocks and tank from bridge

PLANT REPORT NUMBER 17

SUBSTATIONS, NAGOYA, JAPAN

DATES INSPECTED 30–31 OCTOBER 1945, 1 NOVEMBER 1945

Summary.

1. This report covers three primary and two secondary substations; namely, the Inuyama, the Iwakura, and the Nisshin primary, and the Rokugo and the Taiko secondary. The primary stations are located in the suburban and the secondary stations in the urban area of Nagoya. The primary have a total of 330,000 KVA and the secondary 82,000 KVA in transformer capacity, and while this is large, it does not indicate their full importance. The primary stations collect, control, transform, and dispatch current from the hydro generating plants in central Honshu to Nagoya and also to the main transmission lines to Osaka. These three stations covered herein, together with the Mie station, covered in a separate report, are all the primary stations in the Nagoya area. Therefore, collectively they are of utmost importance in the continuous flow of current from its source to consumer as their function is a vital link in the chain of supply. The 2 secondary substations are merely two of a large number of this type of station in Nagoya, but are representative of all such stations, though these did supply electric energy to the Mitsubishi Aircraft Engine Works, a vital war industry. Except for the Rokugo secondary station, all substations were outdoor type. Substations are not producing units and therefore production is not herein calculated, but their importance and function in an enemy economy is in proportion to their size.

2. None of these substations was ever a primary target, but they were damaged at various times during area raids or attacks on adjacent industries, as is explained in detail in this report.

3. Principal damage was done to transformers, oil circuit breakers, control boards, and switch gear, and resulted in a large loss of ability to handle the normal amount of energy. However, since the area served was destroyed simultaneously, the load was likewise lost and the economic value of the loss in substation capacity was negligible. Recuperation of substations is shown to be long and difficult where damage to major equipment occurred. The vulnerability of substations is definitely shown. Although some loss was due to fire from incendiary bombs, that was only because of unusual and peculiar conditions: i.e., location in a crowded inflammable area and the use of inflammable materials in station construction, which is not normally the case in a modern station. The negligible effect of incendiary bombs against a modern station is shown. Serious damage from strafing was done, but is possible only when air defense is negligible and low-level attacks can be made. The damage from high explosive bombing is conclusively shown and the vulnerability to this type of attack is by far the greatest.

4. These stations, with 2 exceptions, were not listed in intelligence information. The 2 exceptions were Inuyama and Iwakura, and these are shown in the Air Objective Folder and also by JTG. However, their evaluation was incorrect in both these documents. No intelligence information was given on the results of damage.

5. The most significant evaluation of the study made of these stations is the importance of these primary substations to the Nagoya and Osaka areas, not individually but collectively. They are vital and necessary links in the supply of hydro generated power from central Honshu to these highly industrialized areas. Their interconnections were such that destruction of one station would not in itself have eliminated any appreciable quantity of energy, as means could have been evolved to circumscribe the damage. But, had all the primary substations been destroyed, together with the local steam plant facilities which were few, most of the electric supply would have been effectively eliminated.

The Plant and Its Function In Enemy Economy.

1. The product of the plant and its importance in enemy economy.

This report covers a group of both primary and secondary substations in or near the city of Nagoya. The names of these substations, together with their function, transformers installed, and KVA rated capacity are as follows:

Name and function	Transformers	Rated capacity, KVA
Inuyama (primary)	3–15,000=KVA 3–5,000=KVA	60,000.
Iwakura (primary)	9–13,333=KVA (3 presently removed)	120,000.
Nisshin (primary)	6–25,000=KVA (3 presently removed)	150,000.
Rokugo (secondary)	1–10,000=KVA 3-phase 15–25,000=KVA (3 spare) 3–4,000=KVA	52,000.
Taiko (secondary)	3–10,000=KVA	30,000.

These stations are not all the primary or secondary substations in the Nagoya area. A substation is an important link in the chain of distribution of electric current from its source of generation to the ultimate consumer, and its destruction would prevent the use of the current. Therefore, these stations were important in the complete electrical system and the individual importance of each must be considered in terms of the question of whether an adjacent station could function as a substitute in case of destruction. The three primary substations covered in this report, together with the Mie Substation, covered in a separate report, comprise all the primary substations in this area and are very important not only to Nagoya but in the collection of control, transformation, and dispatch of current to Osaka. Incoming current from the central Honshu hydro generating plants is handled through these stations and their continuous functioning, not individually but collectively, is necessary in the utilization of this supply. These four stations form a ring around Nagoya and into them come many lines that collect the current from various groups of hydro plants. The stations in turn, are tied into each other, and the capacity of the individual station is such that destruction of any one station could be overcome either by by-passing the station (since transmission lines themselves are unlikely to be destroyed for any distance) or by re-routing generation from the hydro plants via some other transmission line (of which there are many) to another station. Therefore, the importance of these stations lies in their collective function and, in order to eliminate effectively most of the hydro power, all must be destroyed. The hydro power plants themselves are too numerous and too difficult to locate to attempt their destruction. There is some hydro power that comes in directly to secondary substations. Thus, elimination of these four substations would not completely isolate all hydro stations, but would affect the majority and is of vital importance not only to Nagoya but to Osaka as well. This is more fully covered in the final industry report on the vulnerability of the electric power industry. The secondary substations reported herein are by no means all, nor even intended to be the most important in this area, but they are representative, were severely damaged, and adequately illustrate the lasting and effectual damage that can be done. In Exhibit A there is a more complete tabulation of pertinent data, and complete plot plans, diagrams, and other information are available in USSBS files.

2. Physical description of the plant.

For purposes of consolidation, each station is individually listed with its description, attacks, damage, and other information.

Inuyama.

This substation is located approximately 16 miles north of the center of Nagoya, and is one of four principal primary substations in the Nagoya area. All the 154-KV transmission lines that serve Nagoya proper, as well as the principal transmission lines to Osaka, pass through these four stations. This is a very large substation of great importance, not just from its capacity in transformers, but because it is a large concentration point for incoming lines from the hydro power generating stations in the central Honshu area, transforms incoming 77 KV lines to 154 KV for re-transmission on to Osaka, and is a general switching and dispatching station. The station, except for buildings to house offices, dispatching and controls, repairs, warehouses and incidental equipment, is a complete outdoor type. (Exhibit B, photos 4, 5, and 6.) It covers an area of approximately 6 acres and is generally square in shape. Although it operates as one station, it is in two adjacent parts, having originally been constructed by two different companies and then consolidated when the Japan Electric Generation and Transmission Company assumed the operation of all large transmission facilities in Japan. The east part (Exhibit B, photos 1 and 2) was installed by the Daido Electric Power Company in 1926 with one bank of three 15,000 KVA 154/77 KV transformers. In March 1928, a second similar bank was installed, but one bank was removed in February, 1945, due to loss of load. The west part (Exhibit B, photo 3) was installed by the Toho Electric Power Company in 1924 and is primarily a switching section, but has one bank of three 5,000-KVA, 77/33 KV transformers for the purpose of supplying the branch line to Haguro. This station is carried on Japanese records as 60,000-KVA capacity. However, until February 1945, it actually had 105,000 KVA. The following two-circuit transmission lines enter or leave this station:

- Kansai Line—154 KV—From Kasagi PP and others.
- Kiso Line—154 KV—From Suhara PP and others.
- Mino Branch Line—154 KV—Tap from Mino Transmission line that runs from Kawabe PP to Iwakura SS.
- Kansai Line—154 KV—To Yao SS near Osaka.
- Kiso Line—154 KV—To Furukawabashi SS near Osaka.

Kamiya Line—77 KV—Tap from Okuwa line that runs from Okuwa PP and others.

Kawabe Line—77 KV—From Kawabe PP and others.

Iwakura Line—77 KV—To Iwakura SS near Nagoya.

Haguro Branch—33 KV—To Haguro SS in Aichi Prefecture.

While the importance of the station cannot be judged by the transformer loads, the station load during the war years was about 400 million KWH annually, with a peak of 90,000 KW on the east station and 11,000 KW on the west station. Of this load, only about 20 million KWH went to the 33-KV line to Haguro, which is relatively unimportant. In November 1945, the load had dropped to the point where the two transformer banks of 45,000 KVA each were not needed, and one was removed in February as a safety precaution.

This substation was never the subject of a primary attack, but was slightly damaged on several occasions; principally by strafing. The first damage was on 9 June 1945 at 1256 by machine gun strafing of one P-51 plane. There is no record of any raid on this date in the intelligence files. Damage was slight, consisting of one hole in a 77-KV current transformer tank, damaged oil filled bushing, and snapping of one conductor of a 154-KV line that fell on the Haguro 33-KV line and burnt out a potential transformer. The second damage was on 15 July 1945 at 1305 by machine gun strafing of two P-51 planes. No record of any raid on this date is in the intelligence files. Damage consisted of one hole in the tank of three 154-KV oil circuit breakers, bushings broken on 4 others. The oil flowed out of these oil circuit breakers but did not catch fire. In addition, there were 13 line switch insulators, 1 post type and 13 strain insulators broken, one shot hole in cooling water piping for one 5,000-KVA transformer, and one shot hole in an oil storage tank. There was some minor building damage. The third attack was on 30 July 1945 at 0735 by four P-51 planes. There were 6 (presumably 100 lb) bombs dropped of which only 1 fell in the station area and these caused only minor damage. There was also machine gun strafing. Total damage consisted of the breaking of 3 transmission line conductors, a total of 38 holes in 3 small station transformers, mostly through the radiator, and 4 holes in an induction voltage regulator. There is record of 4 attacks in the Nagoya area on this date by Navy planes and it is possible this was done by some of these instead of P-51 planes as reported by station personnel. The fourth damage was on 14 August 1945 at 1253 by machine guns of two P-51 planes. There is no record of any attacks in this area on this date. Damage consisted of a total of 5 holes in main tanks and 8 holes in conservator of three 15,000-KVA transformers. The interiors of the transformers have not been inspected for damage. Oil did not catch fire. In addition, there were 3 bushings broken on these transformers, 4 broken on 154-KV oil circuit breakers, 1 bushing on 154-KV aluminum cell arrester, 1 bushing on 77-KV potential transformer, 1 shot hole in a 77-KV oil circuit breaker, about 60 strain bus insulators broken, and other minor damage. All the damage was repaired reasonably quickly except that, following the attack on 30 July, the east or 154-KV section was discontinued and has been closed since because of the absence of load demand. The damage of 14 August rendered this portion completely inoperable until major repairs are made on the main transformers, which it is estimated will require 6 months. The only protective measures taken were blast barriers (Exhibit B, photos 2 and 6) of wood and sand placed between the main transformers.

Iwakura.

This substation is located approximately 8 miles north of the center of Nagoya and is one of 4 principal primary substations in the Nagoya area. All the 154-KV lines that serve Nagoya, as well as the principal transmission lines to Osaka, pass through these 4 stations. This substation is very large and of great importance, not just from its capacity in transformers, but because it is a large concentration point for incoming lines from the hydro power generating stations in the central Honshu area, transforms incoming 77-KV lines to 154 KV for retransmission on to Osaka, and is a general switching, dispatching and control point for the distribution to Nagoya. The station is an outdoor type except for buildings to house offices, control and dispatching boards, repair shop, warehouses, synchronous condensers and incidental equipment. (Exhibit B, photos 7 and 8). The area covered by the station is approximately 14 acres and is L-shaped. Although it operates as one station, it is in two adjacent parts, having originally been constructed by two different companies. The older portion was installed by the old Toho Electric Power Company and consisted of a switching station only, divided into two separate sections—one for handling all 154-KV lines and the other for 77-KV lines. The newer portion was installed by Japan Electric Power Company and was designed for 4 banks of transformers, each consisting of 3, single-phase, 13,333

KVA transformers, 154 to 77 KV; however, only 3 banks were installed, making a total of 120,000 KVA in transformer capacity. Its purpose was two-fold in that incoming 154-KV transmission could be reduced to 77 KV for use in Nagoya distribution or incoming 77-KV could be stepped up to 154-KV for retransmission on to Osaka. All the separate portions of the station were interconnected with tie-lines, and operated as a single station by the Japan Electric Generation and Transmission Company. Also, there had been installed temporary by-pass lines and plans for reconnecting incoming and outgoing lines in event of the destruction of the station, but this would have eliminated all control and definitely limited the capacity of the outgoing lines, especially to Osaka. The following two-circuit, transmission lines enter or leave this station:

- Nagoya Main Line—154-KV—From Kitagawa switching station, where it can be connected to the Old Hida and New Hida transmission lines from two large groups of hydro power plants or connected to the Tokai transmission lines to Osaka.
- Mino Line—Kawabe side—154-KV—From Kawabe PP and others, and also a tie from Inuyama substation.
- Mino Line—Ozone Side—154-KV—To Ozone SS near Osaka.
- Kachigawa Line—77-KV—From Kachigawa switching station for incoming current from Okuwa, Shizumo and other hydro plants. Can also be used to transmit current to or from the Rokugo secondary substation through connections at Kachigawa.
- Inuyama Line—77-KV—From Inuyama primary SS.
- Okashi Line—77-KV—From hydro plants in Gifu area.
- Iwatsuka Line—77-KV—To Nagoya secondary substations.
- Atsuta Line—77-KV—To Nagoya secondary substations.

This station also had three 25,000-KVA synchronous condensers operating 11 KV from a tertiary winding of the transformers. The importance of the station cannot be judged by its transformer loads, since it receives 77 KV and retransforms it to 154 KV for transmission to Osaka or receives 154 KV and transforms it to 77 KV for Nagoya. The load therefore varies in accord with the requirement of different conditions. The loss of load due to area and industry bombing has been such that the one remaining undamaged bank is ample to care for all present requirements.

This station was damaged by war action only once and that was on 11 August 1945, the day before the end of the war, when it was the object of a strafing attack. No record of any attack is on the intelligence records. Shot holes punctured the tank of one transformer and set the oil on fire; this fire completely destroyed the entire bank of three transformers. (Exhibit B, photo 9). Medium damage was also done to six 154-KV oil circuit breakers and one additional transformer, also light damage to three 77-KV breakers and other minor damage. The bank in which the one transformer was slightly damaged has been completely removed, thus leaving 2 banks in place. Therefore, Japanese records show this station as 80,000-KVA capacity, but one of the banks in place is completely inoperative, and present actual capacity is 40,000 KVA. The only protective measures taken were blast barriers placed around the transformers. (Exhibit B, photo 10). Complete repairs will require at least 6 months.

Nisshin.

This substation is located approximately 4 miles southeast of the center of Nagoya and is one of 4 principal primary substations in the Nagoya area. It is owned and operated by the Japan Electric Generation and Transmission Company. The station was originally designed as an intermediate station for power factor correction and transformation of 77-KV lines to 154-KV for transmission to Osaka. However, this plan was never carried out and the principal function of the station has been as a concentration point for incoming 154-KV and 77-KV lines from hydro power plants and redistribution to the Nagoya area as 77 KV. The station was almost square in shape, measuring about 600 ft by 500 ft, and containing about 7 acres. It is an outdoor type (Exhibit B, photo 11) except for buildings to house offices, control and dispatching boards, synchronous condensers, warehouses, repair shops, and incidental equipment. There were 2 transformer banks each consisting of 3-single-phase, 25,000-KVA, 154/77 KV transformers, making a total capacity of 150,000 KVA. Because the loss of load made all this capacity unnecessary, and because of fear of bombing, one bank of transformers was in the process of being removed to a safe place so that it could be used as spare. (Exhibit B, photo 12). Two of these transformers had been moved out of normal position as well as one oil circuit breaker, bussing, and incidental equipment, but all this equipment was still on the

station property because of lack of transportation. Therefore, it was as much subject to damage, had the station been bombed, as the equipment in use and so their precautions would have been to no avail. Due to the anticipated removal of this one bank, the station is carried on government and company records as 75,000-KVA capacity, but this is not actual capacity, as both the design and equipment in place during the war were 150,000 KVA. There are also two 20,000-KW, rotary, synchronous condensers that operate at 11 KV from tertiary windings of the main transformers. The following incoming and outgoing two-circuit lines connect to the station:

Tenryu Line—154 KV—From Yasuoka Hydro Power Plant and others in central Honshu.

Kushihara Line—77 KV—From Kushihara Hydro Power Plants and others in nearby Honshu.

Kachigawa Line—77 KV—TO Kachigawa and Rokugo secondary substations and tie to Iwakura primary substation.

Mizuho Line—77 KV—To Mizuho and other secondary substations.

Higashi Line—77 KV—To Showacho secondary substation.

Narumi Line—77 KV—To a large group of secondary substations as well as tie line from Tokayama primary substation.

This was a very important station to the Nagoya area. The maximum current ever handled was 140,000 KW, of which 110,000 was from the 154-KV lines and 30,000 from the 77-KV lines. The group of hydro stations connected to the incoming lines had a capacity below that of this substation, which accounts for this load being below station capacity. Those plants connected to the 154-KV lines generated at 11 KV, which was transformed at the respective plants to 154 KV for transmission purposes. In case of loss of this substation, production from these plants could have been diverted through Matushima switching station to Inuyama, but line limitations would have made this impractical and the loss to the Nagoya area would have been very serious. There would have been no possible method by which to change the 154-KV incoming line to 77 KV in order to temporarily jumper the station.

This station was never damaged by any war action. There was one incendiary bomb raid on 7 January 1945 and another on 17 May 1945, but neither did any damage. Intelligence records show that on 7 January 1945, 4 B-29 aircraft dropped 4 tons of IB and a few 100-lb HE bombs on urban area of Nagoya and on 17 May 1945, 457 B-29 aircraft dropped 3,609 tons of IB on south urban area of Nagoya. These are evidently the raids on which the incendiary bombs fell on this station, but it was never a primary target. Blast barriers made of wood and sand had been placed around the transformer bank (Exhibit B, photo 13), but no other protection was provided and such vital equipment as the 154-KV oil circuit breakers (Exhibit B, photo 14), and other similar items (Exhibit B, photo 15) were totally unprotected.

Rokugo.

This was one of the largest secondary substations in Nagoya. It is owned by the Chubu Electric Supply Company, the distributing company for this area. Located in the northeast section of the city of Nagoya, it furnished current to a large section of this part of the town and in addition, was one of two (the other is Taiko) that served the large Mitsubishi Aircraft Works. The station was an indoor type with all equipment located indoors except one 10,000-KVA, 3-phase transformer and 1 bank of three 4,000 KVA transformers. It was housed in a group of buildings, some of brick and plaster with steel truss and tile roofs and others of wood; all of very old construction. (Exhibit B, photo 16). The station proper is rectangular in shape, approximately 350 ft by 450 ft, containing 3.7 acres. Adjacent to it was an electrical store room area (Exhibit B, photo 20), about 140 ft by 240 ft, containing 0.8 acre, making a total for the whole station of 4.5 acres. In addition to controls, switches, bussing, and such associated apparatus, there was one 10,000-KVA, 77/11-KV, 3-phase transformer (to feed Mitsubishi Aircraft Works) fifteen 2,500-KVA, 77/11-KV, single-phase transformers (of which 3 were classed as spares) and three 4,000-KVA, 77/11-KV, single-phase transformers for general use, making a total station capacity of 52,000 KVA. In addition, there was a 10,000-KVA, synchronous condenser.

This station was never a primary target, but was severely damaged on 14 May 1945 during a raid on the north urban area of Nagoya when 411 B-29 aircraft dropped 2516 tons of IB. A large number (quantity unknown) fell on this station. The fire resulting from the burning of the combustible buildings on and adjacent to the station property completely destroyed the electrical store room (Exhibit B, photo 20), testing shop, numerous other miscellaneous buildings, and partially destroyed the office, switchroom (Exhibit B, photo 7), 11- and 77-KV, oil, circuit breaker

room (Exhibit B, photo 18), the transformer room housing the group of 2,500 KVA transformers, as well as the 10,000-KVA, 3-phase transformer located adjacent thereto. (Exhibit B, photo 19). All the oil circuit breakers, the control board (Exhibit B, photo 17), and the transformers were put completely out of service, and while minute examination has not been made, it is expected these are all completely ruined. The 10,000-KVA transformer will require a complete rebuilding. The three 4,000-KVA transformers were not damaged and were placed back in operation on 22 July 1945. This is the only portion (except the synchronous condenser) of the station that was not badly damaged. All the load sheets were destroyed by fire, but officials advised that the station was carrying a load of about 32,000 KVA, and, since restoration of the one remaining transformer bank, the load is from 2000 to 2300 KVA. No protective measures of any kind had been taken. Complete repairs to all equipment and buildings will require at least six months.

Taiko.

This was a comparatively small secondary substation, but important in that it supplied the Mitsubishi Aircraft Engine Works. However, another station (Rokugo) also supplied the same industry and each of these stations was practically a standby for the other. The station was owned by the Chubu Electric Supply Company, the distributing company for this area, and was installed only to supply the Mitsubishi plant. The station was a complete outdoor type except for buildings to house the control room, offices, and warehouse. The area covered by the station was about 175 ft by 300 ft, or 1.2 acres. There were three 10,000-KVA 77/11-KV transformers with 6 oil circuit breakers on the 77-KV side as there were 2 incoming 77-KV lines. Underground cables feed 11 KV from the station to the Mitsubishi factory.

This station was never a primary target but was damaged on three occasions during raids on adjacent areas. On 13 December 1944, 71 B-29 aircraft dropped 96 tons of HE and 85 tons of IB on the Mitsubishi Aircraft Engine works. Six incendiary bombs fell on the station, burning the warehouse but otherwise doing no damage. On 22 December 1944, 48 B-29 aircraft dropped 130 tons of 500-lb incendiary clusters. One struck a 77-KV oil circuit breaker breaking a bushing and another damaged a lightning arrester, but damage was so slight that there was not even a service interruption. On 7 April 1945, 154 B-29 aircraft dropped 614 tons of 500-lb HE bombs with the Mitsubishi factory as the primary target. Four bombs struck the station and completely ruined it. One bomb fell near, and another made a direct hit on the transformer bank (Exhibit B, photo 21), splitting the cases on the transformers, setting fire to the oil, and completely demolishing them beyond any possible repair. (Exhibit B, photos 21, 22, 23 and 24). Another made a direct hit on the group of oil circuit breakers, splitting the tanks, setting the oil on fire and completely ruining them. (Exhibit B, photo 25). Another hit near the 77-KV bus structure tore it up completely. This bomb apparently did not completely detonate as a portion of the casing was found in the crater. (Exhibit B, photo 26). This station was completely destroyed; the damage was greater than that at any other station seen that had been hit by high explosive bombs. The damage that was done with so few bombs was remarkable. No protective measures of any kind had been taken.

At the time of the raid of 7 April 1945, the Mitsubishi works was in the process of dispersing to the mountains and much equipment had already been removed. Therefore, the load was only abuot one-third of normal. This same raid destroyed what was left of Mitsubishi, so there was no need to rebuild the station. It would have required at least 6 months to rebuild it.

3. All the primary substations were owned by the Japan Electric Generation and Transmission Company and the secondary substations by the Chubu Electric Supply Company, which is the electric distributing company in this area. Information was supplied by the following persons:

S. Saito—director of Japan Electric Generation and Transmission Co., and district manager of Tokai district in which these stations are located.

S. Yoneda—asst. district manager and district engr.

G. Inouke—director and chf engr of Chubu Electric Supply Co.

H. Ogawa—station master Inuyama Station.

M. Okaeda—station master Iwakura Station.

H. Nagata—station master Nisshin Station.

G. Iwai—station master Rokugo Station.

4. There was a total average of 100 employees for all the 5 stations in this report. This number did not vary greatly throughout the war and was stable all during the year. Operators worked 2 shifts and others, such as maintenance men, worked one. Because of damage to stations and complete elimination of one, the number of employees is now down to about 75.

Attacks.

In no case was any station ever the object of a primary attack, but was damaged as a result of an area raid or attack on some adjacent industrial target. Under each station is given attack data, where it is available.

Effects of Bombing.

1. Physical damage.

a. This information is covered individually under each substation, as well as briefly in Exhibit A.

b. No effort was made to prepare a bomb plot of each station, but effects can be seen from photos in Exhibit B.

2. Production loss.

a. The simultaneous destruction of the area or industry served neutralized any actual loss by damage or destruction of the stations, as load was lost at the same time. However, where possible, load data is given under each individual report.

b. No substitution or modification was necessary as the load was destroyed.

c. Reasons for loss of production.

(1) Refer to tabulation under Exhibit A or to individual station reports.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss was caused through protective measures.

(4) No loss was caused through absenteeism or unusual inefficiency.

(5) No loss was caused by any shortage of essentials.

3. Recuperability cycle.

a. Where damage was slight, repairs were made with no loss of time. Where damage was heavy, i.e., involving the loss of a transformer or other major equipment, no effort had been made to effect repairs. Estimates are given in each individual report, and those stations heavily damaged will require at least 6 months to be put back in original operating condition. This estimate is based on having supplies and repair facilities available. With the widespread damage and the fact that the electrical equipment manufacturers were either damaged or set up to manufacture other types of equipment, it is doubtful that any substantial amount of repair could be completed in less than one year.

b. The level of production reattained is an uncertain factor, for with the load lost, there was no need to attempt to restore capacity to its former level. The part which remains and which is operable is stated in each station report.

c. The undamaged portion of each station can be utilized.

4. Vulnerability.

a. The study of these stations shows conclusively the vulnerability of substations. The damage done by strafing was extensive and proves that this type of attack is desirable. However, air defense must be practically nil to make strafing possible. Since vulnerability must be considered from the standpoint of unfavorable conditions of attack, and methods that will secure the maximum of damage and thus, the longest recuperability cycle, it is not believed that strafing is a practical attack method. The damage done by fire caused by incendiary bombs does not indicate that substations are vulnerable to this type of attack. Contrary to general practice, the Japanese use considerable wood and other inflammable material in the construction of their substations, particularly the older ones and the distribution substations. These were located in the centers of densely populated areas among highly inflammable surroundings, and so were subject to the same degree of damage as their immediate vicinity. But where this particular condition does not exist, incendiary bombs do not cause any damage to substations. This is shown in the attacks on Nisshin and Taiko. Substations are particularly vulnerable to HE bombs and the definite proof of this is at Taiko, where four 500-lb bombs completely destroyed the entire station. Heavy tonnage per acre is not required and although generally the small area covered by a substation does make the target somewhat difficult to locate and hit from high altitudes, when they are hit by HE bombs, the results are very destructive and lasting.

Intelligence Check.

1. *a.* The OSS report did not list any of these substations.

b. The Air Objective Folder 90.20 for the Nagoya area issued by the office of Assistant Chief of Air Staff, Intelligence, listed only 2 of these stations, namely Inuyama and Iwakura, correctly located them and briefly evaluated them, but their evaluation in the summary was incorrect.

c. The JTG listed the Inuyama and Iwakura stations and correctly located them. However, under the significant evaluation, it states that these two stations control the hydro power to Nagoya and Osaka which is not true.

2. No photo interpretation of damage was made.

3. No photo interpretation of recuperation or dispersal was made.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

The primary substations were modern and well operated, although there was obviously an excess of equipment. The effect that the destruction of these stations would have had is most impressive. However, it is equally impressive that this effect would only result if they were destroyed collectively. The damage results that can be obtained from high explosive bombs is most definitely shown at the Taiko station.

EXHIBIT A—NAGOYA SUBSTATIONS

Name, type and owner	Rated capacity KVA	Transformer equipment	Rotary condensers KVA	Lines and voltages: Incoming KV	Lines and voltages: Outgoing KV	Dates of attacks	Damage by	Principal damage[3]	Remarks
Inuyama (primary) owned by[1]	60,000	3-15,000 154/77 3- 5,000 77/33	None	6-154 1-77	1-154 2-77 2-33	9 June 1945	Strafing	Very slight—1 current and 1 potential transformer and broken insulators.	Serves Osaka primary and Nagoya secondary.
						15 July 1945	Strafing	Holes in tank of 3-OCB Broken insulators Damage light	
						30 July 1945	Strafing and bombs	38 holes in station transformers. No fire.	
						14 Aug 1945	Strafing	13 holes in main transformers. Bushing and insulators broken.	
Iwakura (primary) owned by[1]	120,000	9-13,333 154/77 (3 presently removed.)	3-25,000	4-154 6-77	2-154 4-77	14 Aug 1945	Strafing	Completely destroyed 3 main transformers by fire. Medium damage to one main transformer and 3-77 KV OCB, etc.	Serves Osaka Primary and Nagoya secondary.
Nisshin (primary) owned by[1]	150,000	6-25,000 154/77 (3 presently removed.)	2-20,000	2-154 2-77	8-77	None	None		Serves Nagoya secondary.
Rokugo (secondary) owned by[2]	52,000	1-10,000 3-phase 15-2,500 (3 spare.) 3-4,000 all 77/11	1-10,000	2-77	Various 11 underground cables.	14 May 1945	IB	Heavy—all transformers except 3. All circuit breakers; control room; principal buildings—all by fire.	Serves Nagoya distribution and Mitsubishi Aircraft Engine Works.
Taiko (secondary) owned by[2]	30,000	3-10,000 77/11	None	2-77	Various 11 underground cables.	13 Dec 1945	IB	Slight—warehouse burned.	Serves Mitsubishi Aircraft Engine Works.
						22 Dec 1944	IB	Slight—bushing on OCB and lightning arrester.	
						7 April 1945	500 lb HE	Heavy—all transformers and OCB station completely destroyed.	

NOTES: [1] Owned by Japan Electric Generation and Transmission Co. [2] Owned by Chubu Electric Supply Co.

[3] More detailed damage given in description of each substation.

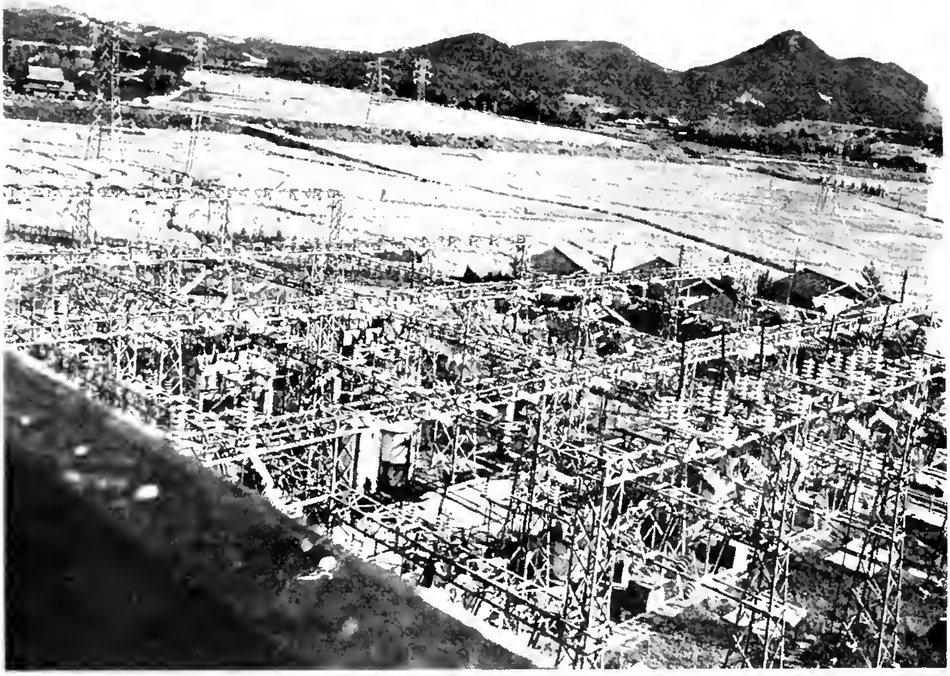

Photo 1—Inuyama—General view, east substation, 154-KV section

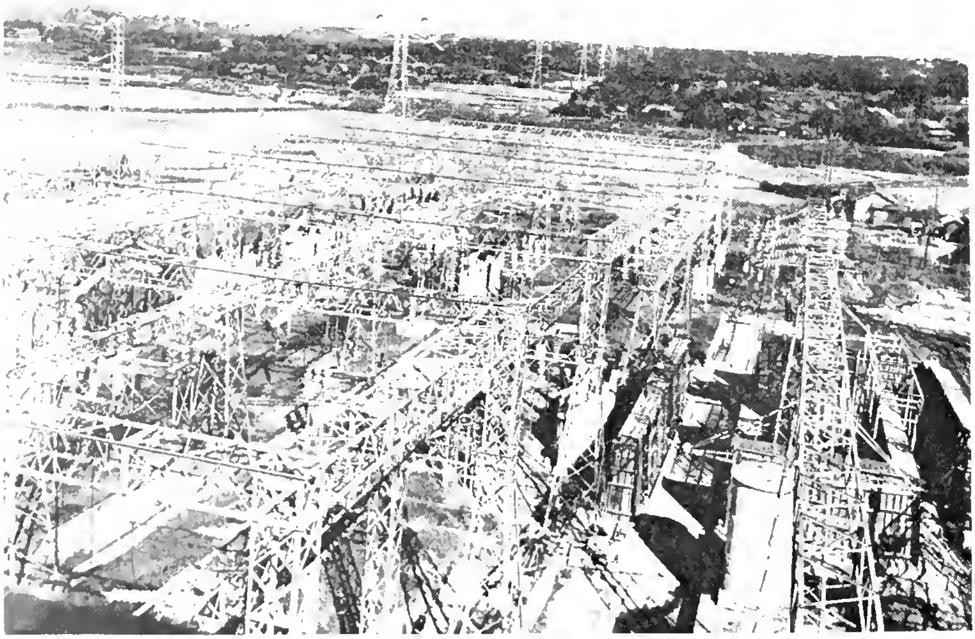

Photo 2—Inuyama—General view, east substation, 77-KV Section and Transformer Bank. (Note bomb barriers)

Photo 3—Inuyama—General view, west substation

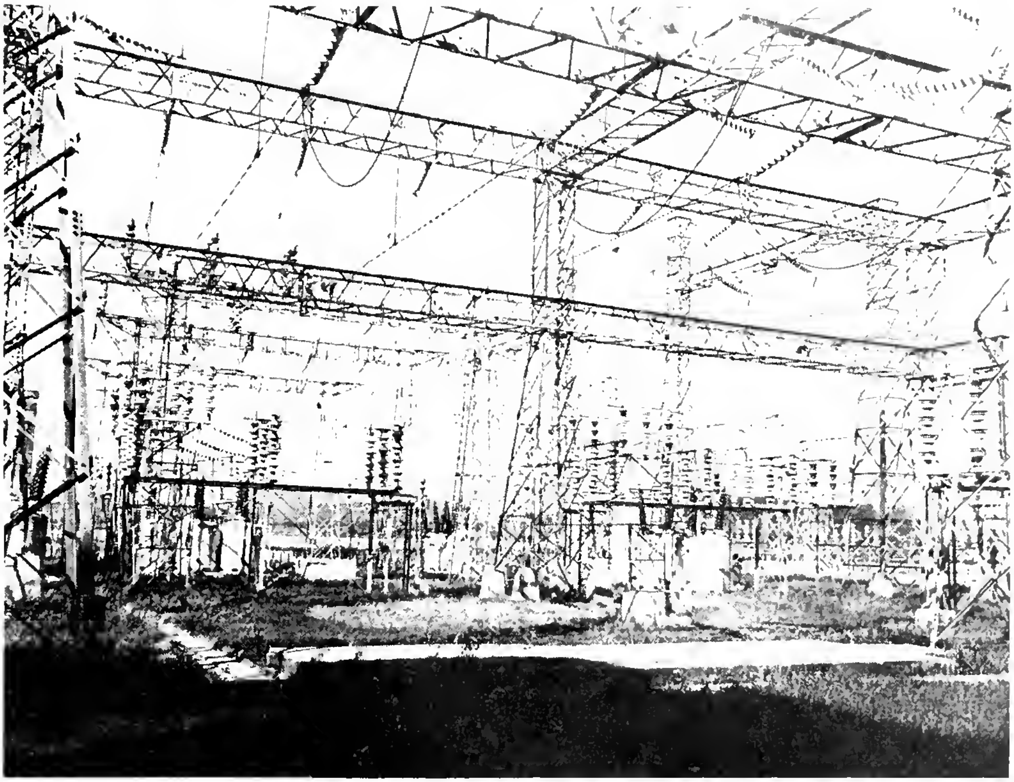

Photo 4—Inuyama—View of 154-KV section of east substation

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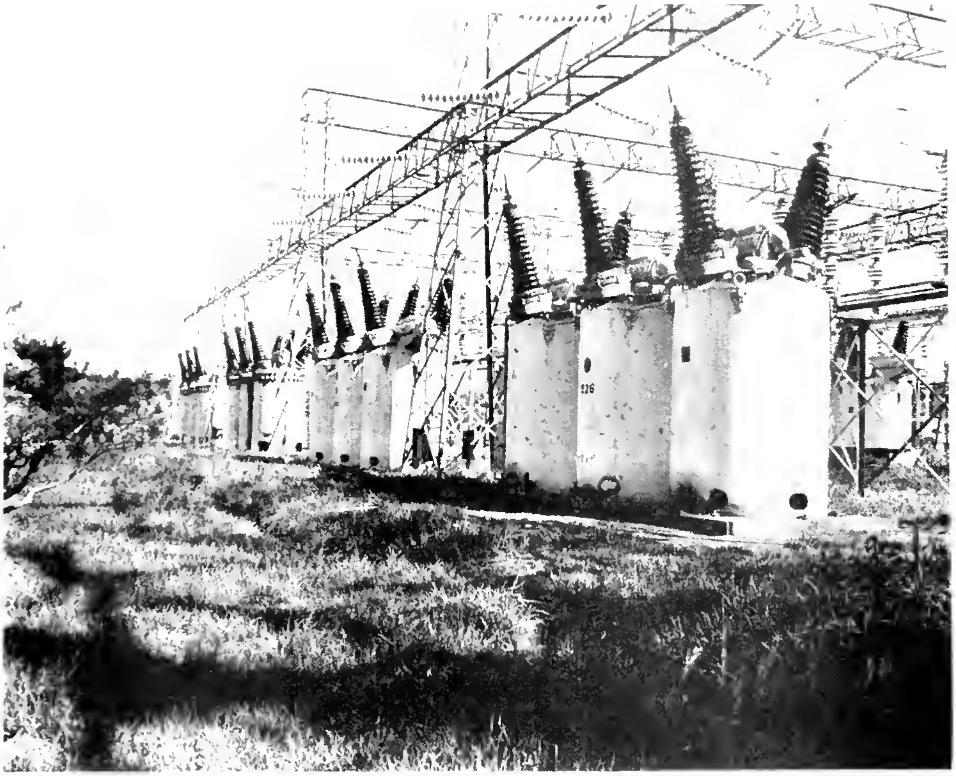


Photo 5—Inuyama—Bank of 12—154-KV, oil, circuit breakers

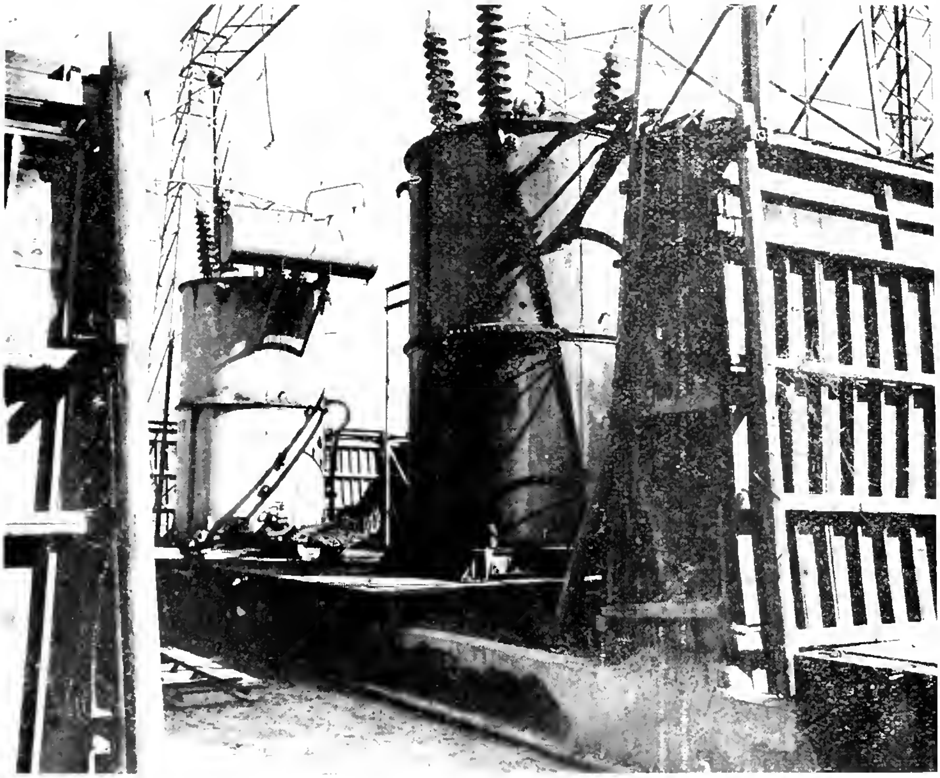


Photo 6—Inuyama—Close view of 15000-KVA transformers, showing bomb blast barrier

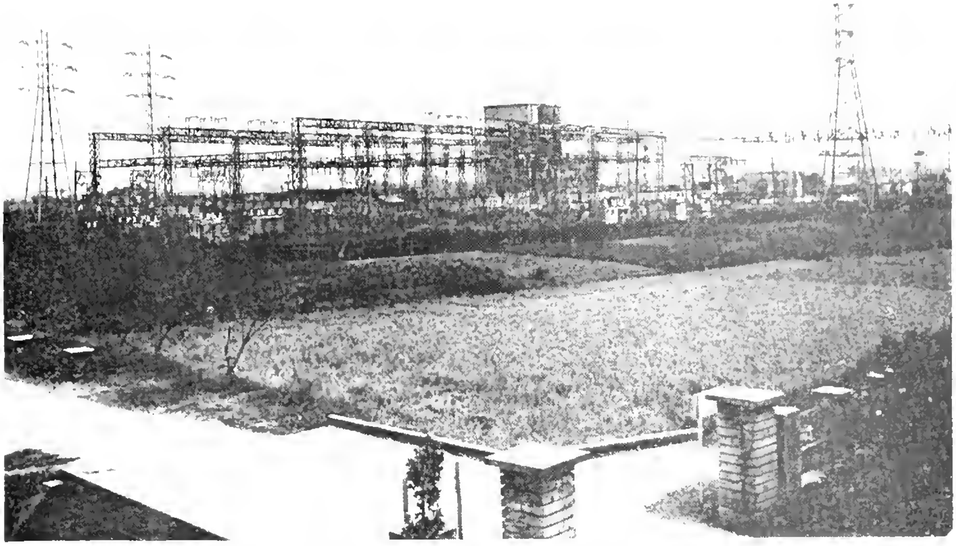


Photo 7—Iwakura—General view south section (Old Toho)

Photo 8—Iwakura—General view north section (Old Nippon)

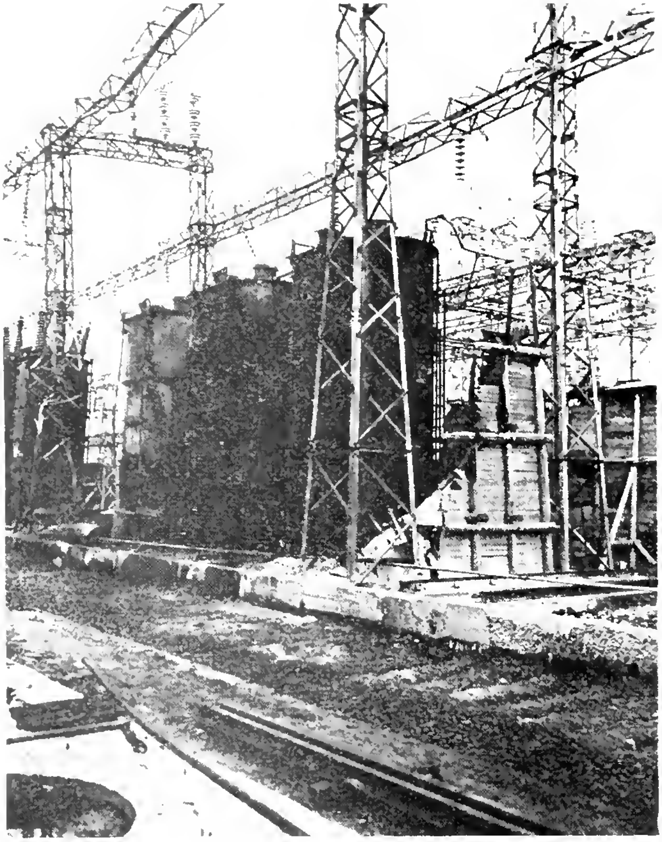


Photo 9—Iwakura—Bank of 13,333 KVA transformers damaged by fire

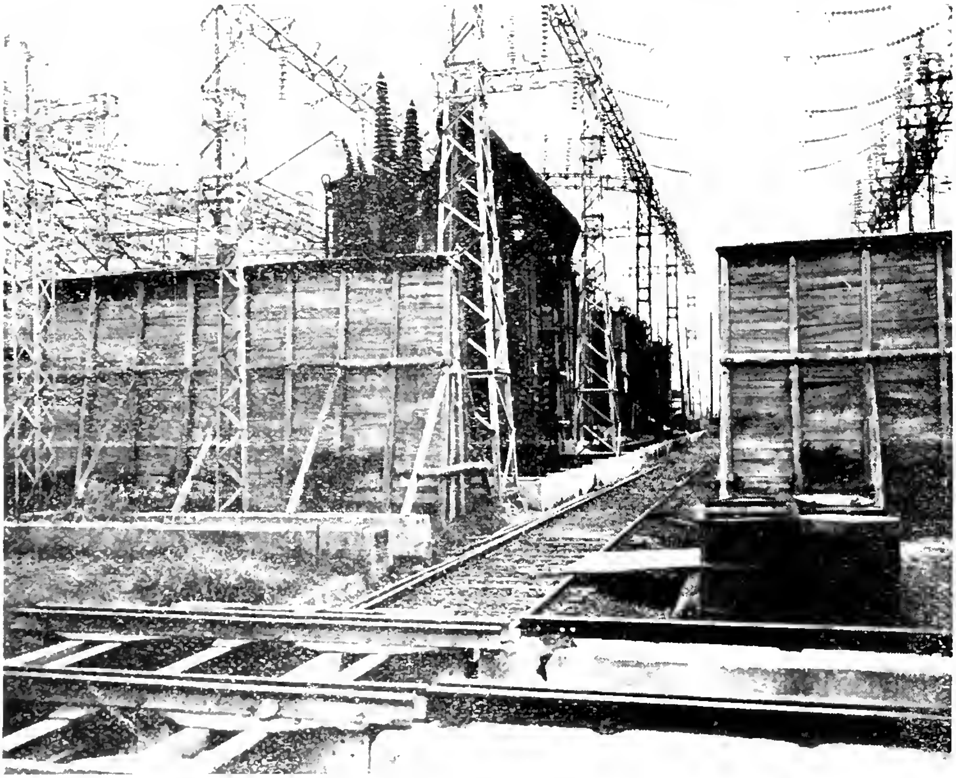


Photo 10—Iwakura—Transformer banks, damaged transformers on far end

Photo 11—Nisshin—General view of station

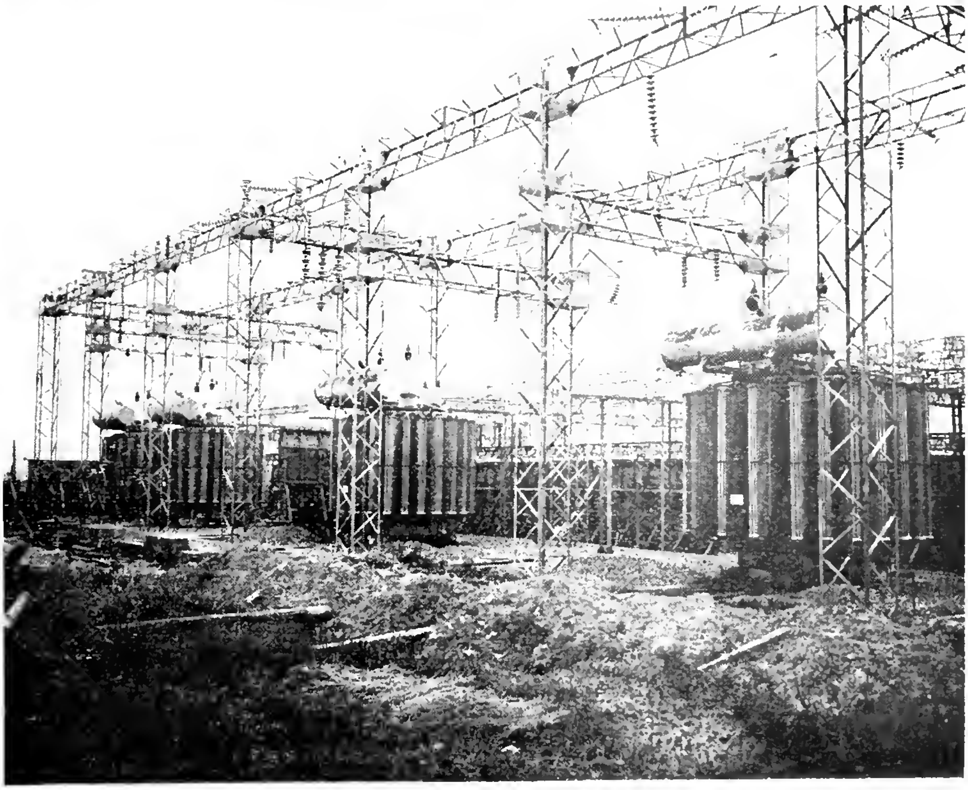


Photo 12—Nisshin—Transformers, 25,000 KVA each. Blank spaces are where transformers had been removed for safety

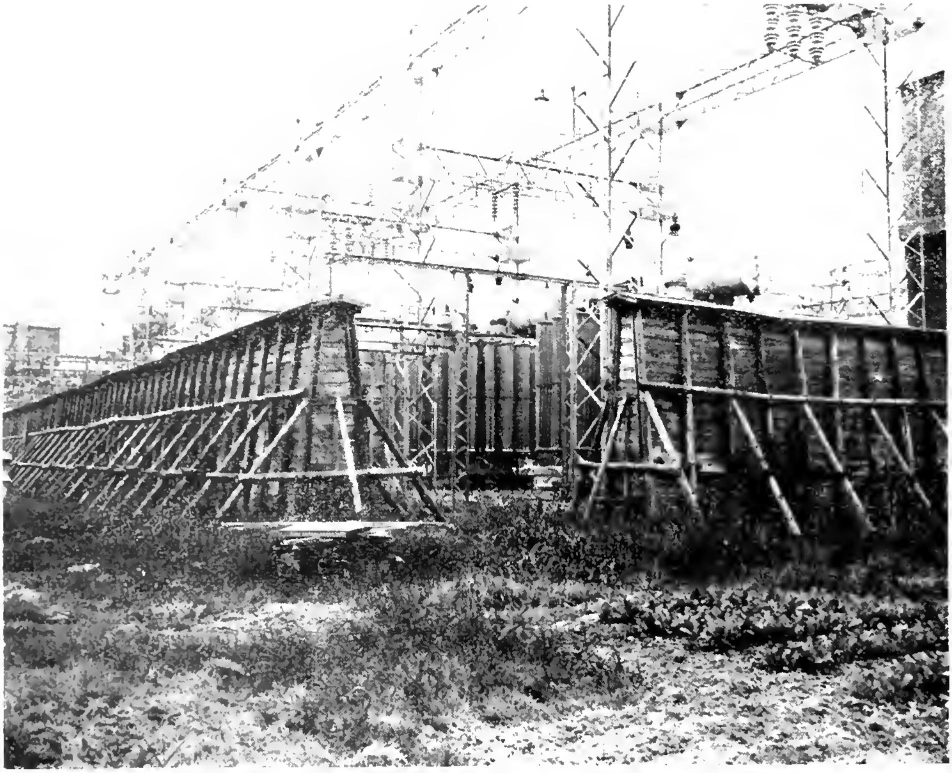


Photo 13—Nisshin—Transformer bank showing blast barriers

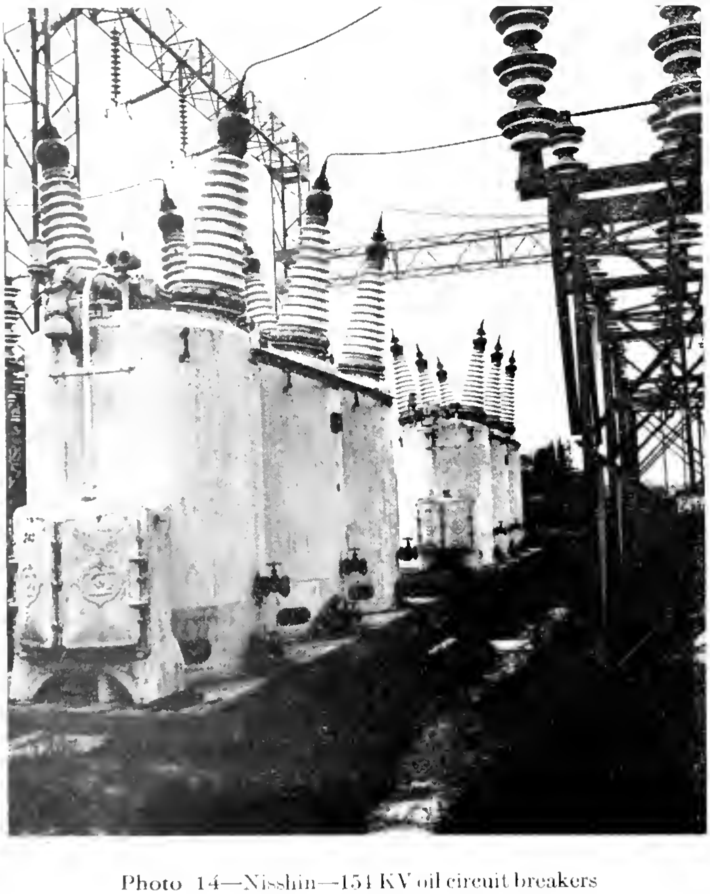


Photo 14—Nisshin—154 KV oil circuit breakers

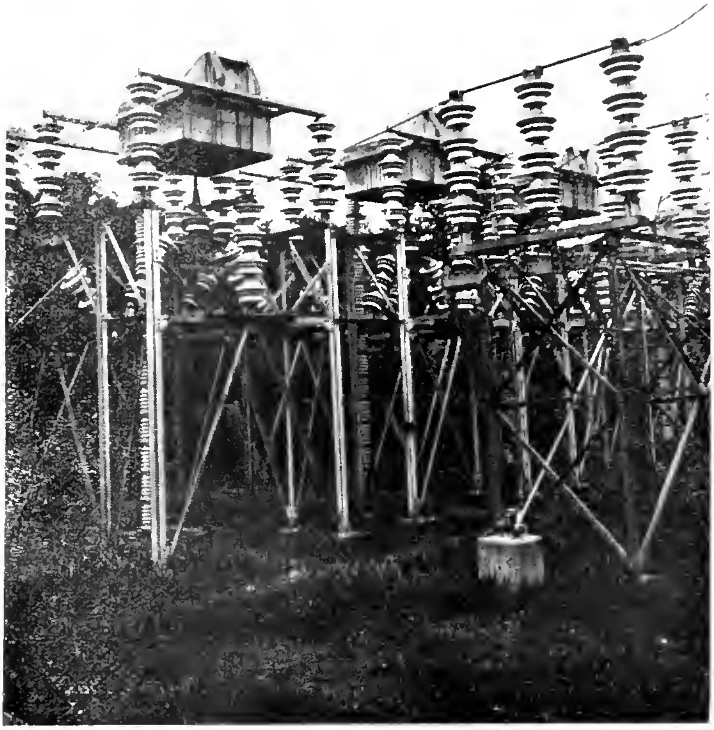


Photo 15—Nisshin—Lightning arrestor installation

Photo 16—Rokugo—General view of damaged station

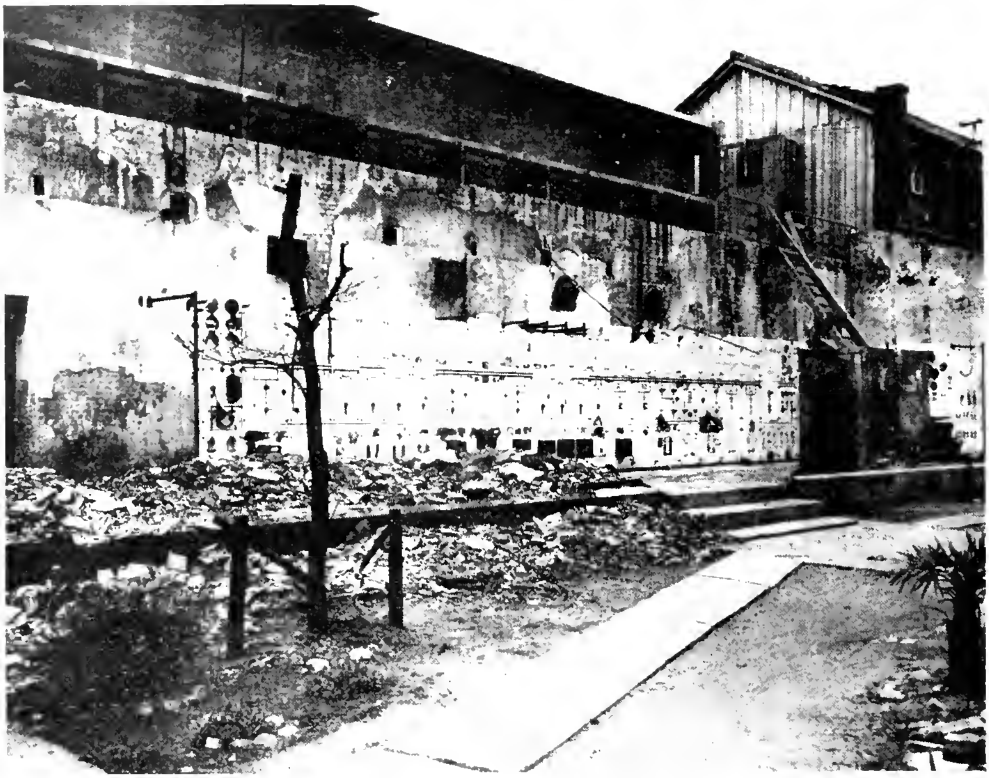


Photo 17—Rokugo—Remains of control board

Photo 18—Rokugo—77-KV oil circuit breakers destroyed by fire

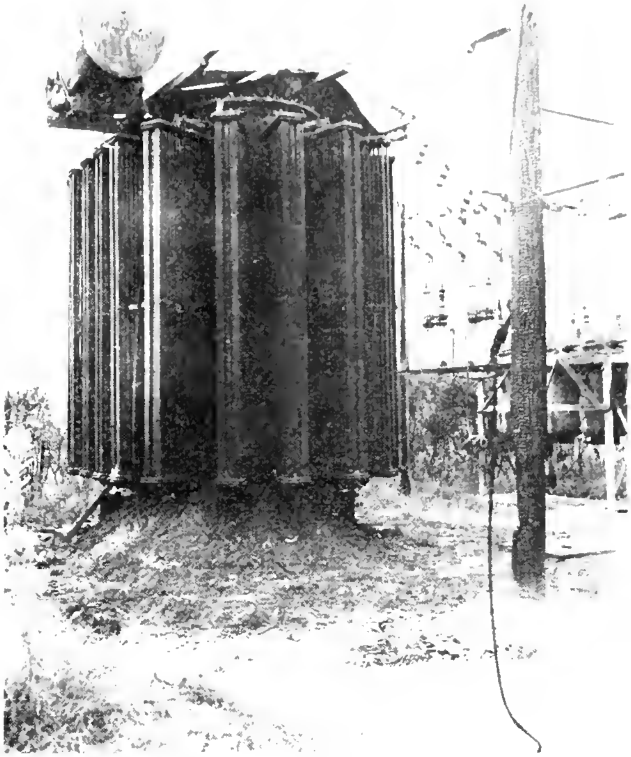


Photo 19—Rokugo—10,000-KVA 3-Phase transformer completely ruined by fire

Photo 20—Rokugo—General view burned electrical storeroom adjacent to substation

Photo 21—Taiko—Transformer bank of 3—10000-KVA transformers completely destroyed by direct hit and fire

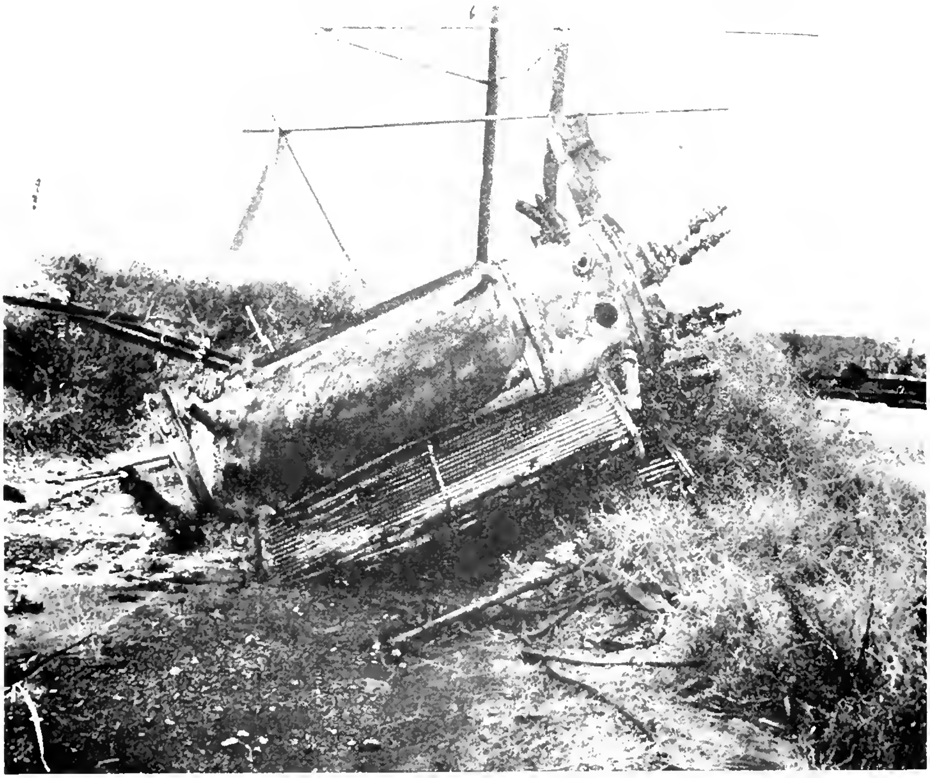


Photo 22—Taiko—Transformer No 1 of destroyed bank

Photo 23—Taiko—Transformer No 2 of destroyed bank

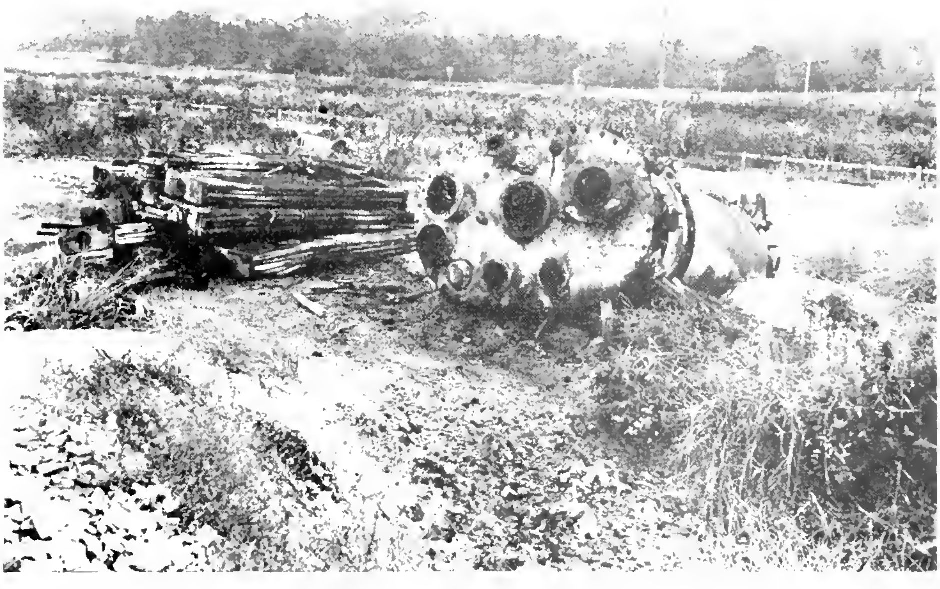


Photo 24—Taiko—Transformer No 3 of destroyed bank

Photo 25—Taiko—Destroyed group of oil circuit breakers

Photo 26—Taiko—Casing of 500 lb bomb found in bottom of crater at station

PLANT REPORT NUMBER 18

MIE SUBSTATION YOKKAICHI

MIE PREFECTURE (NEAR NAGOYA) JAPAN

DATE INSPECTED 28 OCTOBER 1945

Summary.

1. The Mie Substation is located in Mie Prefecture, approximately 25 miles southwest of the city of Nagoya. It had a transformer capacity of 100,000 KVA, and was a very important factor in the electrical supply to the highly industrialized area on the west side of Ise Bay, which includes oil refineries, naval installations, and harbor and dock facilities.

2. This station was never a primary target, but was heavily damaged on 9 July 1945 during a raid by the Twentieth AF on the Utsube Oil Refinery. The station was evidently attacked, either in error, or as a target of opportunity, as the primary target was located over 2 miles away. There were 16 hits of 500-lb GP bombs in the station area, of which 6 were effective.

3. The principal damage was destruction of the entire transformer capacity, consisting of a total of 6 transformers, which rendered the station completely inoperative. No production loss was sustained because of their ability to make substitution by temporary means through another substation. Recuperation would require about one year. Vulnerability of such stations is demonstrated conclusively by the large and lasting damage caused by a very few bombs.

4. No intelligence data was ever given on this station, nor was the damage either assessed or reported.

5. It is very significant concerning this station to note that the heavy damage was caused by a comparatively small amount of bombing effort. However, it is also significant that temporary measures could, and did, overcome the loss of the station. While this was, to some degree, due to loss of load from area and industry bombing, it is evident that the bombing of a single substation produces no desirable economic effect and that only by a combination of the destruction of the majority of substations, together with steam generating plants, within an area, can the electric power supply be effectively destroyed.

The Plant and Its Function In Enemy Economy.

1. Product of plant and its importance in enemy economy.

The Mie substation is the main primary substation transforming transmission line voltage of 154 KV and serving the very important Yokkaichi area south of the city of Nagoya. This area, located on Ise Bay, contains, besides the port and city of Yokkaichi, the Utsube River Oil Refinery, Ishihara Smelter and Refinery, the Mitaki River Oil Refinery, Second Naval Fuel Depot, and many other important industrial and naval installations. In 1942 this station averaged approximately 20 million KWH monthly, with maximum demand of 42,500 KW. In 1943 the monthly average was about the same, with demand up to 44,500 KW, and in 1944 the maximum demand was 42,500 KW, average demand 34,000 KW, maximum daily delivery 800,000 KWH, and monthly average slightly under 20 million KWH. The station was completed and put into operation in 1940. Its total transformer capacity was 100,000 KVA.

2. Physical description of plant.

This substation is located approximately 25 miles southwest of the city of Nagoya at about the intersection of 136°36′ longitude and 34°56′ latitude and 1½ miles due east of the railroad station of Shiohama and 3 miles southwest of the town of Yokkaichi. The station area is approximately 400 ft square, containing about 4 acres. (Exhibit A). Except for a small building housing the control room and dispatcher's office, a transformer repair building, and minor storage buildings, all equipment is located outdoors. (Exhibit C, photo 1 for general view). Incoming voltage is 154 KV, which enters the station from the west in 2 circuits on the same towers. These circuits are tapped to the main 154-KV line that runs from Iwakura Substation in Nagoya to the Yao Substation in Osaka. The 154-KV section contains 2 154-KV, air blast breakers and interconnecting bussing and disconnects. There are 2 banks of transformers. One bank consists of three 20,000-KVA and the other has three 13,333-KVA transformers, all with rating of 154/77 KV and with 11-KV tertiary winding. There is one 20,000-KVA transformer spare. The 77-KV section contains potential and current transformers, disconnects, oil circuit breakers, and usual bussing. There is also an installation of static condensers. There are 4 outgoing 77 KV circuits, 2 of which feed the distribution substations at Yokkaichi and Tsu,

and the other 2 go to the Navy substation for use by the Navy and industrials.

3. The station is owned by the Japan Electric Generation and Transmission Company. Information was secured from Mr. S. Saito, director and head of the Tokai district in which this station is located, and Mr. G. Matsudo, station master.

4. The station normally has 20 employees, and this number has not changed throughout the war. Two shifts are worked.

Attacks.

This station was subjected to bombing with HE bombs on the night of 9 July 1945 at approximately 2330. Records do not show that this station was ever a primary target, so evidently it was damaged during a raid on the Utsube Oil Refinery, which was the primary target of attack on 9 July 1945. In this raid 61 a/c of the Twentieth AF dropped 469 tons of 500-lb general purpose HE bombs. There were 16 hits on this station.

Effects of Bombing.

1. Physical damage.

a. Of the 16 hits that were made within or adjacent to the station area, 10 were on the north side of the 77-KV section and did only minor fragmentation damage. The others did the following damage:

Two hits near the towers supporting the incoming 154-KV lines tore down the lines and damged supporting insulators, although towers remained intact.

One hit in center of 154-KV bus structure completely demolished about half of this structure with all supports, and fragmentation damaged both the 154-KV air blast breakers and supporting structures. (Exhibit C, photos 6 and 7).

One direct hit near the end of the transformer bank did the greatest damage. This hit was directly beside a 20,000-KVA transformer and damged it beyond repair. The oil was set on fire, and this fire enveloped the complete transformer bank and burned for 18 hours. All 6 transformers were completely ruined (the spare transformer was in the repair shop at the time), and will require major repairs and rebuilding. The complete bus structure over the transformers was destroyed. Wood and sand blast barriers placed around the transformers for protection added inflammable material to the fire and did more harm than good. (Exhibit C, photos 2, 3, 4 and 5).

One hit was directly on one set of potential and current transformers in 77-KV section. (Exhibit C, photo 8). Equipment was severely damaged.

One hit was directly on one end of bank of static condensers, completely demolishing about half of the condenser capacity and doing heavy fragmentation damage to the cases, insulators, and racks of the balance. (Exhibit C, photo 9). The only protective measures taken were the wood and sand blast barriers that had been placed around the main transformers, and which proved ineffective because of their construction of inflammable material.

b. An accurate bomb plot showing exact location of hits and the damage has been prepared and is shown in Exhibit A.

2. Production loss.

a. Although the station was rendered completely inoperable, no production loss occurred. The station had over-capacity to start with, and, at the time of the damage, much of its usual load had been lost because of damage to the industrial area served. Also, ways and means were devised to by-pass the station.

b. Definite means of substitution and modification were obtained. The station was supplied by two 154-KV circuits tapped on the 2-circuit Iwakura-Osaka transmission line. When the bombing rendered the transformers useless, one of the circuits was cut at the junction point where the feeders to this station tapped the main lines from Iwakura Substation. Connections at Iwakura were changed so that this circuit became 77-KV instead of its usual 154 KV, and a jumper was placed completely around the station, thus connecting the outgoing lines directly to feeders from the Iwakura Substation. Exhibit B shows the normal connections diagram and temporary emergency connections. Thus, service was established; however, there was no control at Mie Substation and there were certain other limiting factors. The substation of Iwakura could not have furnished this load had not its own load been curtailed by industrial and area bombing. The transmission line to Osaka was definitely limited, but, again, the loss of load in Osaka made this unimportant. However, this is an example of what can be done to provide continuous service during an emergency.

c. (1) The causes for loss of this station were the complete loss of transformer capacity because of bombing and resultant fire.

(2) No loss was caused through diversion of labor, materials, or other facilities.

(3) The protective measures taken did add to the fire loss, although to what extent is problematical.

(4) No loss was caused through absenteeism or inefficiency.

(5) No loss was caused through shortage of essential materials.

3. Recuperability cycle.

Based on ability to secure necessary materials, it would require approximately one year to effect complete repairs. This is on the assumption that no spare transformers were available elsewhere; for these damaged transformers will certainly require a complete factory rebuild job. The fact that a means of substitution and modification was used successfully in this case does not mean quick recuperability. The loss of any single station can usually be overcome, but, when a number of stations are put out of service, no substitution is possible and recuperation is as long as is required to rebuild completely. No attempt to effect any repairs had been made.

4. Vulnerability.

This is an excellent example of the vulnerability of substations. Of the 16 bombs that struck the station, only 6 were within effective range, but these, and especially one, rendered this station completely useless. It can, therefore, be said that as small a quantity as four-tenths of a ton per acre will produce lasting damage to this type of installation.

Intelligence Check.

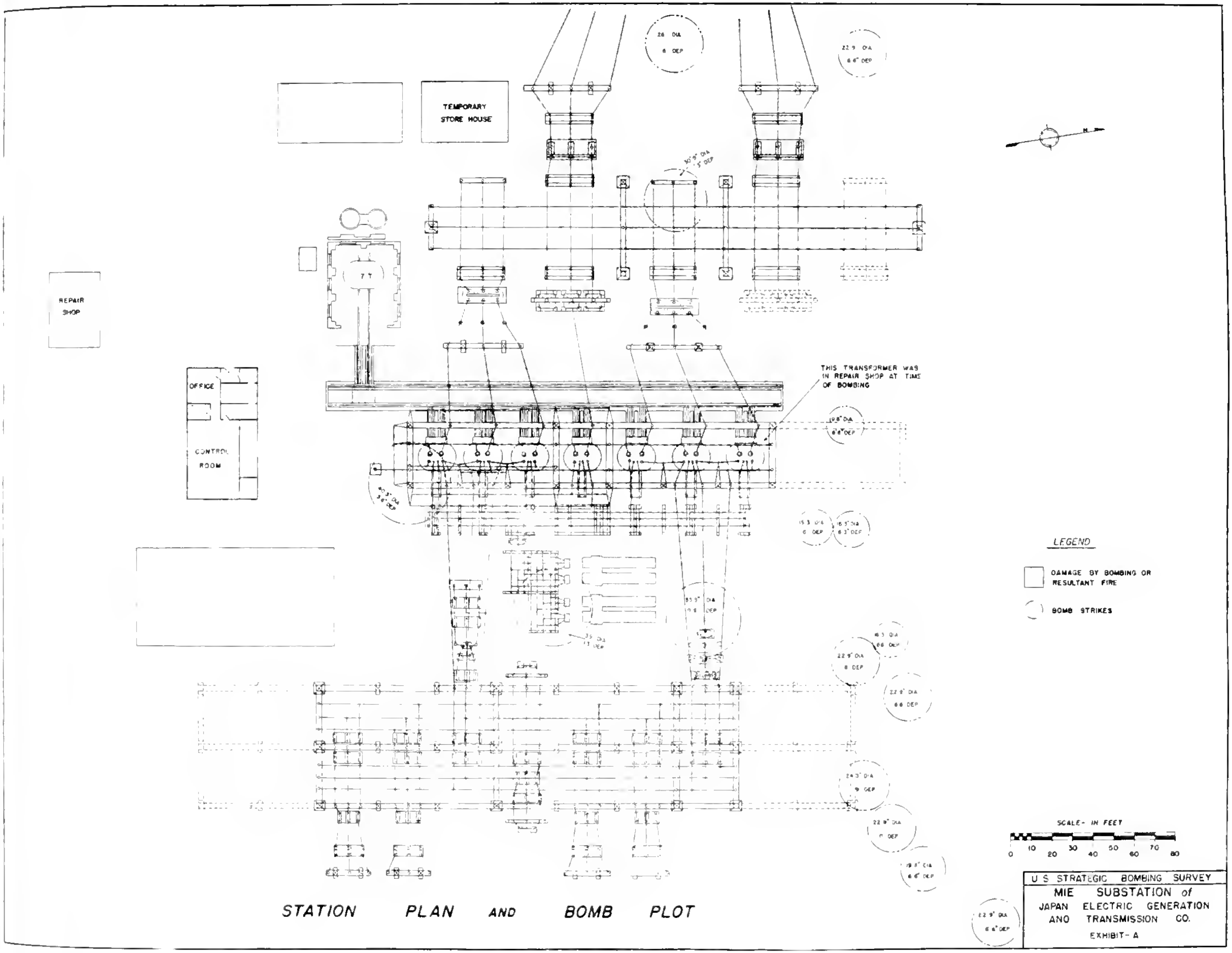
1. No pre-raid data was found on this station in any of the intelligence materials.
2. No damage assessment was made.
3. No photo interpretation was made.

Data Relevant To Other Studies.

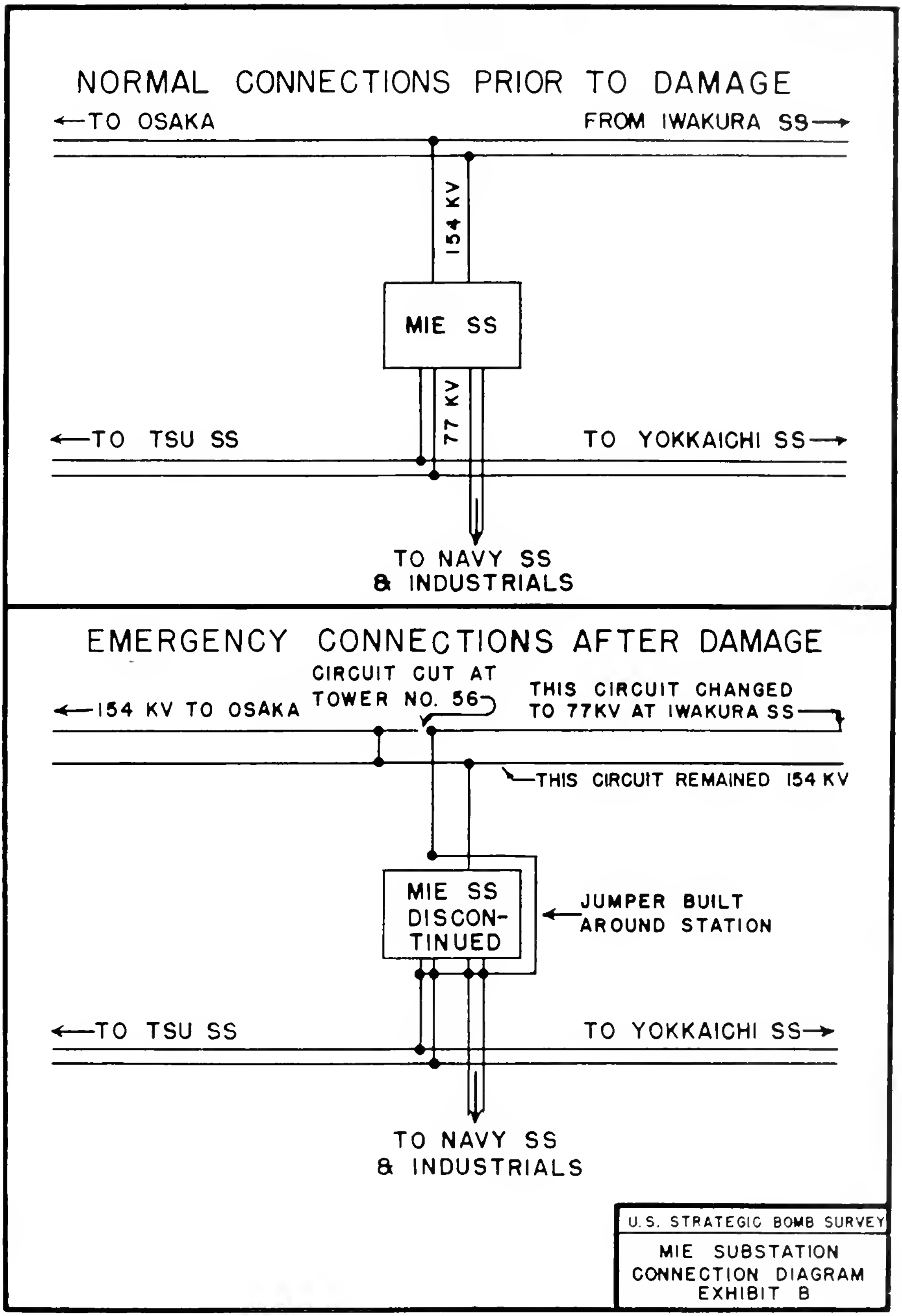
None.

Evaluations and Impressions.

This was a new and modern station, and its maintenance and operation were good. The ability to overcome the loss showed good judgement and execution. The fact that heavy damage was caused by a small quantity of bombs demonstrates the vulnerability of substations.



STATION PLAN AND BOMB PLOT


NORMAL CONNECTIONS PRIOR TO DAMAGE
TO OSAKA
FROM IWAKURA SS
154 KV
MIE SS
77 KV
TO TSU SS
TO YOKKAICHI SS
TO NAVY SS & INDUSTRIALS
EMERGENCY CONNECTIONS AFTER DAMAGE
154 KV TO OSAKA
CIRCUIT CUT AT TOWER NO. 56
THIS CIRCUIT CHANGED TO 77KV AT IWAKURA SS
THIS CIRCUIT REMAINED 154 KV
MIE SS DISCON- TINUED
JUMPER BUILT AROUND STATION
TO TSU SS
TO YOKKAICHI SS
TO NAVY SS & INDUSTRIALS
U.S. STRATEGIC BOMB SURVEY
MIE SUBSTATION CONNECTION DIAGRAM EXHIBIT B

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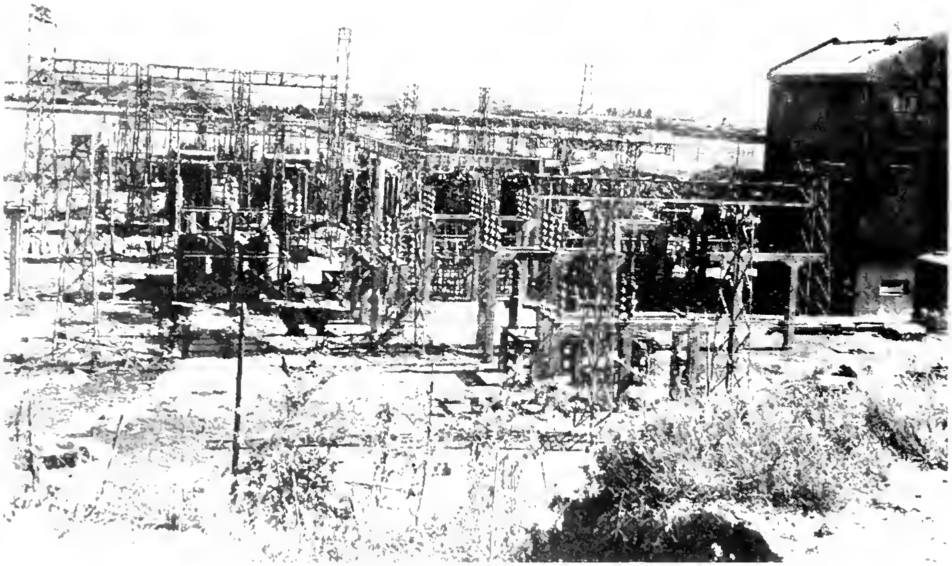

Photo 1—General view of station from 154-KV end

Photo 2—Bomb crater from direct hit at end of transformer bank

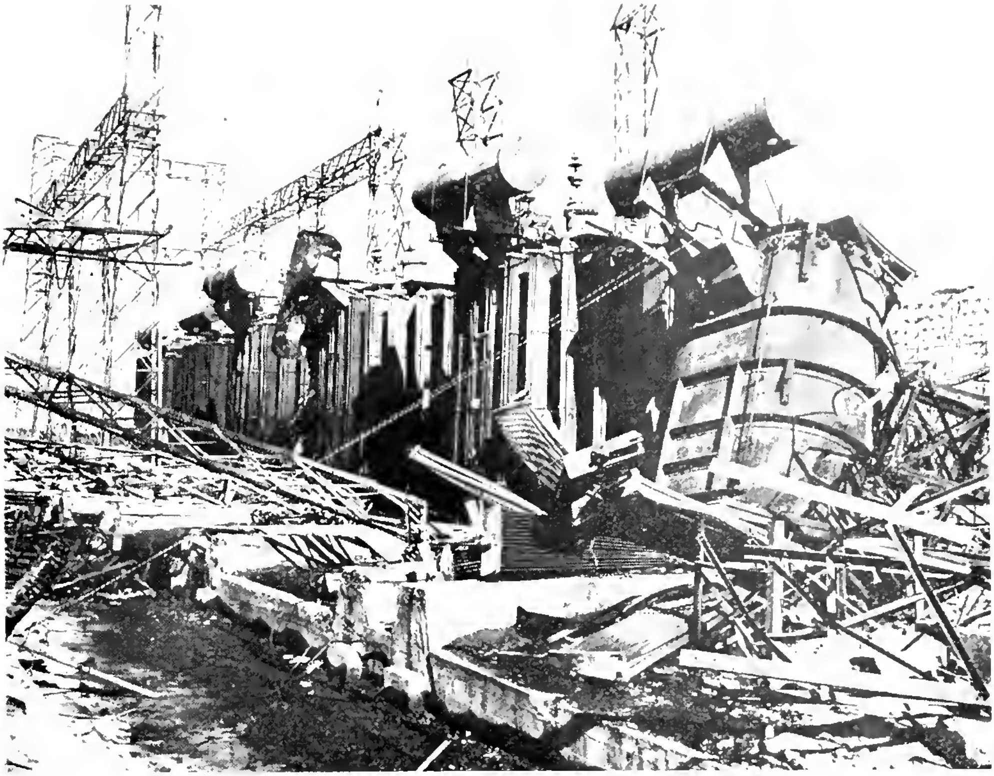

Photo 3—Bank of 6 damaged transformers

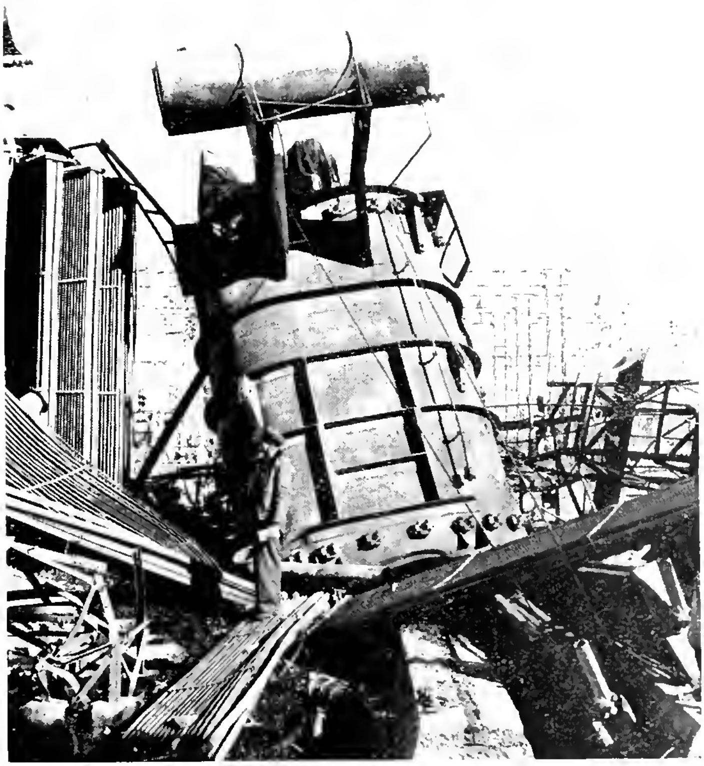

Photo 4—Damaged 20,000-KVA transformer
(end transformer in photo 3)

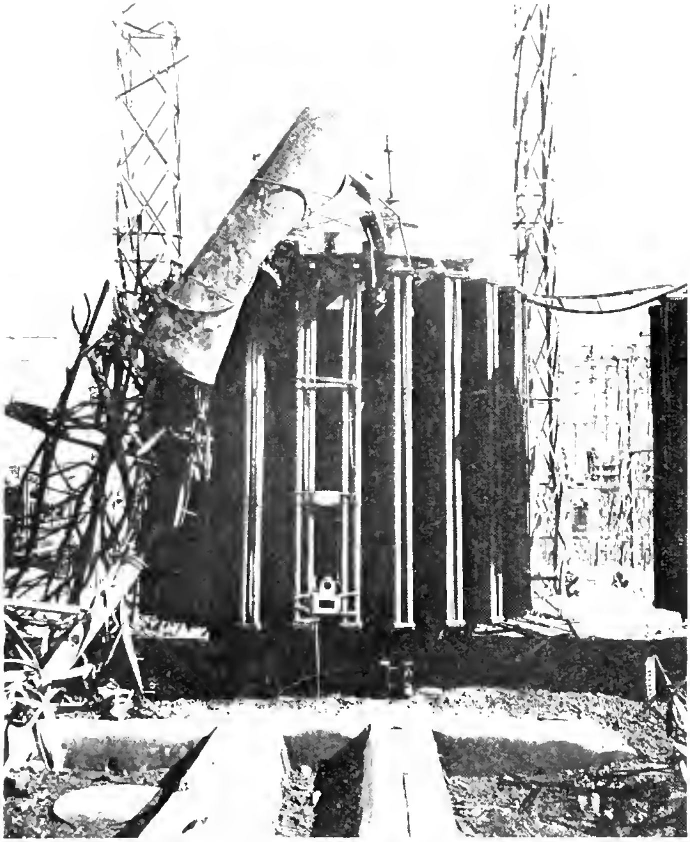

Photo 5—Damaged 20,000 KVA transformer (third transformer in photo 3)

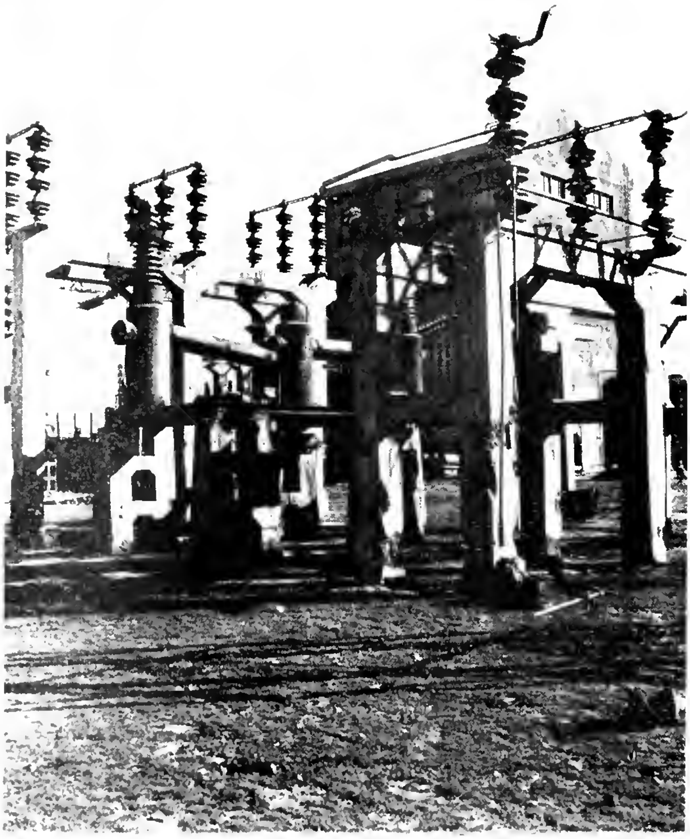

Photo 6—Damaged 154 KV air blast breaker. Note fragmentation marks

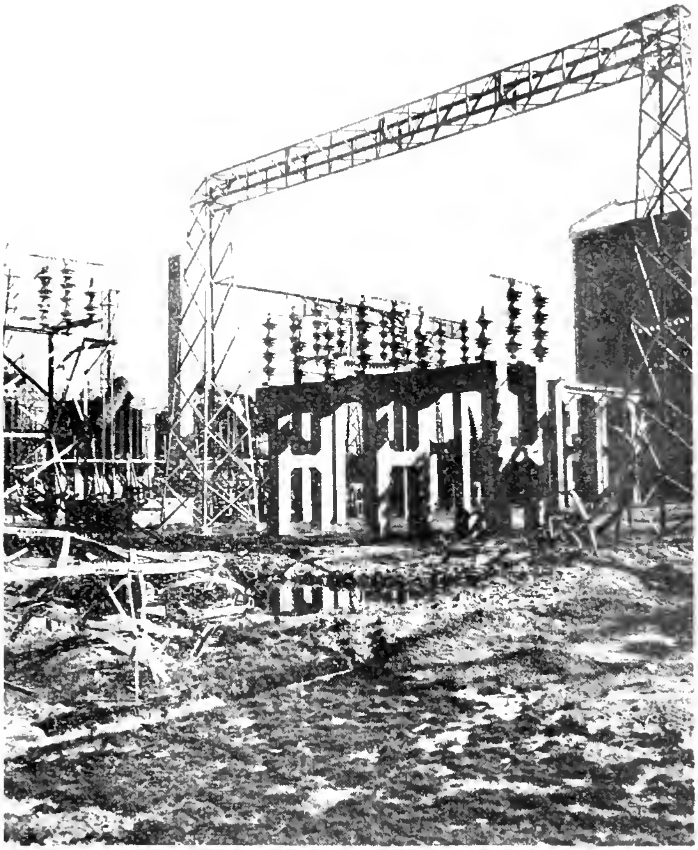

Photo 7—Direct hit on 154 KV bus structure

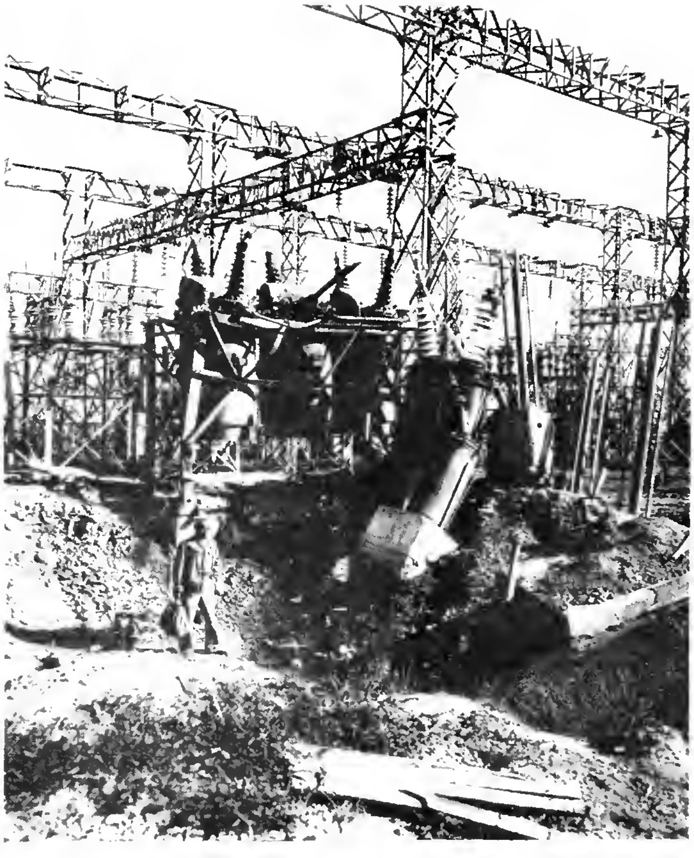

Photo 8—Bomb crater from hit near 77 KV potential transformers

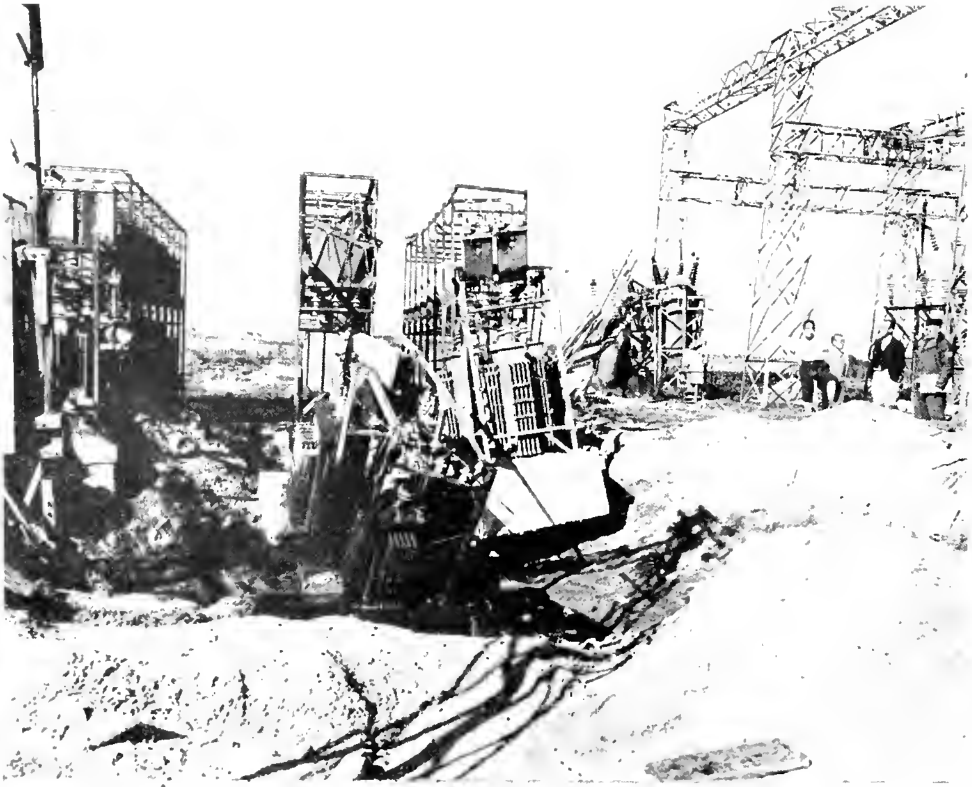

Photo 9—Direct hit on static condensers

PLANT REPORT NUMBER 19

SECONDARY SUBSTATIONS

OSAKA, JAPAN

DATE INSPECTED 1 NOVEMBER 1945

Summary.

1. This report covers 6 secondary substations owned by the Kansai Electric Supply Company, which is the electric distributing company in the Osaka area. These substations are located in Osaka and are not all the substations there, but the principal damaged ones. Their sizes are relatively small, and these 6 total 66,700 KVA in transformer rated capacity. It is difficult to point out any specific importance in the enemy economy other than that substations in general are an important link in the chain of electric supply from generation to the consumer, and since Osaka was an important area, these substations were equally important in proportion to their size.

2. These substations were never a primary target, but were damaged in conjunction with various area raids or attacks on adjacent industries.

3. Principal damage was done to transformers, switchboards, control wiring, switch gear, and buildings. While much damage was caused by fire, this was mostly the result of their being located in crowded areas adjacent to highly inflammable buildings, and, to some extent, of being housed in buildings with roofs of combustible material. Since the area they served was destroyed, the production loss by the station destruction was of no economic importance. It is shown that secondary substations are highly vulnerable and that recuperation is a long process.

4. These substations (with one exception) had not been listed in intelligence reports, and no specific damage assessments made. However, secondary substations are too numerous to list all of them, and unless serving some particularly valuable specific industry of great military importance, would not be individually listed.

5. These stations were seriously damaged by fire, which would give the impression that this type of installation was particularly vulnerable to incendiary bomb damage. This is not, however, generally true, and had they been isolated from surrounding combustible buildings and been constructed, as substations usually are, completely of non-combustible materials, they would have been practically undamaged from fire, except that caused by high explosive bombs.

The Plant and Its Function In Enemy Economy.

1. The product of the plant and its importance in enemy economy.

This report covers a group of damaged secondary or distribution substations in the city of Osaka or its immediate vicinity. The names of these substations together with their capacities are as follows:

	KVA
Nakamoto	6,000
Sakurajima	17,500
Sakaigawa	7,000
Dotombori	6,000
Ishizugawa	28,200
Yamatogawa	3,000

These stations are not all the substations in Osaka, but are the principal secondary stations that were damaged. A substation is an important link in the chain of distribution of electric current from its source of generation to the ultimate consumer, and therefore its destruction prevents the use of the current. These stations were important in the complete electrical system, and the individual importance of each, as a single unit, is not herein emphasized. In Exhibit A there is a more complete tabulation of pertinent data.

2. Physical description of plant.

For purposes of convenience, each station is separately listed with its description, attacks, damage, and other information.

Nakamoto Substation.

This station was contained in a single reinforced concrete building, with a hip-type, steel-covered roof, built about 25 years ago. Exhibit B, photo 1 shows a view of the front of the station where it received a direct hit. Exhibit B, photo 2 shows an inside view from the front end of the building with the 10-KV switching structure on the left and transformers in cells on the right. Induction regulators are located directly in back of the transformer cells. Exhibit B, photo 3, gives a view looking toward the front of the station at the level of the mezzanine floor on which are located the control board at left, and shows the top of the 10-KV switching structure and

the transformers in cells. The battery was located in the far left corner on the first floor, with the control panel and the charging motor generator set on the mezzanine floor directly above. The 3-KV switching structure is on the mezzanine floor at the rear end of the building with all lines going out overhead.

The attack on this substation was on 14 August 1945 at 1100. It was hit by one GP bomb at the front end of the building (Exhibit B, photo 1), damaging the building severely, damaging the storage battery on the ground floor at the front right hand corner of the building, and damaging one bushing on the nearest transformer. (Exhibit B, photo 2, shows a view taken from the rear of the substation). No bombs dropped on any of the surrounding buildings.

Two operators were used in this station on each shift with other men doing maintenance work. During this raid 4 persons were slightly injured. For employees' protection air-raid shelters were provided. Because of changed conditions due to the bombing of the surrounding area, this substation will be abolished. Information was furnished by K. Suguira, station master.

Sakurajima Substation.

This substation was located in a heavily industrialized area, which manufactured airplane propellers, metal products, etc. (Exhibit B, photos 5 and 6). The control and switching equipment was housed in a one-floor, reinforced concrete building with a hip-shaped roof, steel sheet covered, while the transformers were installed outdoors to the left of this building. (Exhibit B, photo 4) In order to improve the power factor, static-type condensers were installed.

This substation was attacked on 24 July 1945 during a general attack on this area and suffered a direct hit on the building, resulting in a fire which, with flames from burning adjoining factories, completely destroyed the building and contents. The fire damaged the outdoor transformers, but these had not been examined, at time of inspection, to determine whether the core and coils were damaged beyond repair. Exhibit B, photo 6, shows a view of an adjacent factory destroyed in the same raid. It is believed that even if this substation had not been hit directly, it would have been destroyed by the fire from the adjoining factories, as station personnel stated that the substation was surrounded by a sea of flames, and that 1,000 to 1,500 persons perished in the adjoining areas. It will be noted in photos 4 and 5, that a reinforced concrete wall about 7 ft high had been installed on 2 sides of the substation building.

This station used 4 employees per shift and at the time of the raid 3 were present, but none was injured.

Since the surrounding area was completely destroyed, this substation will not be rebuilt. Information was furnished by T. Ozawa, station master.

Sakaigawa Substation.

This substation, located in a small factory and residential area, was of reinforced concrete construction with hipped wooden roof, and had been extended and revamped several times. As a result, it is housed in a number of rooms which make a very poor arrangement, especially the 20-KV switchgear of the cell type construction. The 3-KV switching is of the open type supported on a frame work (Exhibit B, photo 7), and other parts are of the cell construction type. At this station the transformers are installed outdoors. The present, high tension, oil circuit breakers have an interrupting capacity of 300,000 KVA. For improving the power factor, there were installed outdoors ten 150-KVA, 3-KV, capacitor units.

No direct hit was made on this building, but IBs hit the adjoining building on the north and flames were communicated to this substation, damaging the control panels, the control wiring, and the 3-KV switching. (Exhibit B, photo 7). No persons were injured in this station and no protecting shelters were installed. Information was furnished by I. Yomishita, station master.

Dotombori Substation.

This substation was mostly of reinforced concrete construction; some of the older parts were of brick, and all had wooden roofs. All equipment, except the static capacitors, was housed indoors, with the 3-KV and 11-KV switchgear and transformers on the ground floor and their control on the second floor. In a separate concrete building with a wooden roof was located a 1,000-KVA, 3-KV, synchronous condenser with its control, and outside of this building were foundations for ten 150-KVA, 3-KV, static, capacitor units, but only 3 were in place.

There was one direct hit by an IB on the roof at about the middle of the control room. The resulting fire destroyed nearly all of the control board and followed the control wiring to the first floor, but did no damage to the 3-KV switching. (Exhibit B, photo 8). Also, as a result of this hit, the wooden roof of the building in which the synchronous condenser was located burned, and falling embers destroyed the control. The synchronous condenser escaped damage, but is now exposed to the weather as the roof has not been repaired.

An oil tank outside the substation was damaged by fire.

Although, at the time of this raid, 5 men were in the station, none was injured. Information was furnished by J. Doi, station master.

Yamatogawa Substation.

All equipment was housed in brick stucco-covered buildings, with wooden rooves. The 3-KV switching, transformers, battery and charger, and control panels were located in the larger room, while the 10-KV switching was housed in a separate smaller room. At the time of inspection, this 10-KV switching had been completely disassembled, but other damaged parts had not been disassembled. This station was built about 30 years ago, and, since it is located in a badly damaged area, it will be abolished.

This station received no direct hit, but burned because of fire from surrounding burning buildings which set the roof on fire. Falling embers damaged the 3-KV switchgear of open construction, transformers, battery, charger and its control, the main control in the main room, as well as the 10-KV switching in the adjoining room. Exhibit B, photo 9, shows the main control panels with 3-KV switching in the rear, with the battery charger and the control panel at the left. One transformer can be seen back of the 3-KV switchgear. The transformer bushings and fittings were damaged, but the oil inside did not catch fire, and therefore these can be easily repaired. This is true of all circuit breakers, but no protection against weather has been made.

At this station 4 men are employed, and no one was injured. There had been no shelters provided. Information was furnished by U. Sakamoto, station master.

Ishizugawa Substation.

This substation occupies an area of about 200 by 250 ft and is of the outdoor type, with the exception of the 3-KV switching and main control panels (Exhibit B, photo 10), which were located in a brick-faced, reinforced concrete building with a wooden roof in one corner of substation area. Along one side, next to this, was the water pumping equipment for some of the water-cooled transformers, housed in a wooden building. A short distance away, across the entrance road, was located the wooden warehouse which contained spare bushings for the transformers and the oil circuit breakers, oil, and 3 induction regulators. Exhibit A gives a tabulation for the number of incoming lines, transformers, outgoing lines, capacity, and voltage ratio of transformers. The layout of the outdoor substation was simple and spacing large, but otherwise it had no special features.

This substation was subjected to an attack by IBs and, according to M. Yamauchi, master of the station, three 26-lb IBs and 25 small bombs were dropped with high accuracy on the buildings of this station. None of the buildings across the narrow road from these buildings was hit. All the buildings were burned. At the time of the raid, one of the 4,200-KVA, OIWC, main transformers was in the repair shop, and the core and coils were completely destroyed as well as the bushings. The tank can be cleaned and refinished for further use. The warehouse was completely destroyed as was the pump house. The roof of the building in which the control and 3-KV switching were located was set afire, and falling embers completely destroyed the control panels, and badly damaged the 3-KV switching. No protective covering had been provided at time of inspection. (Exhibit B, photo 10). A few shelters had been provided for employees. One man was injured in the raid and died 10 hours thereafter as a result.

3. These various substations are owned by the Kansai Electric Supply Company, which is the electric distribution company in the Osaka area. Information was obtained from the various masters of the substations.

4. The number of employees at each substation is given under the general description for each substation where data were definite.

Attacks.

Under each station is listed the date of the damage. In no case was any station the subject of a specific attack, but was damaged as a result of an area raid or an attack on some adjacent industrial target. These attacks, all by the Twentieth AF, are listed as follows:

City of Osaka.—90.25

Mission 42. 13 March 1945; 275 A/C of the 73rd, 313th, and 314th Bomb Wings participated; time of attack was 1457Z to 1825Z; altitude from 5,000 to 9,400 ft.

Bombs dropped:

194.5 tons E-28 . . . . (500#IC)
812.0 tons E-36 . . . . (500#IC)
671.4 tons E-46 . . . . (500#IC)
54.7 tons M-47A2 . . . . . (100#IB)

Damage: 8.1 sq mi destroyed; 13 number targets destroyed or damaged. See D/A #24. No bomb plot available.

SAKI URBAN.—90.25

Mission 258. On night of 9/10 July 1945, 73rd Bomb Wing participated, dropping a total of 778.9 tons on primary and 19.6 tons on opportunity, between 100233K-100406K, from 10,000-11,350 ft, 1/10 clouds over target.

Type bombs	Over primary	Over opportunity
	tons	tons
AN-M47A2 (100#IB)	367.3	6.3
E-36 (500#IC Open 5000′)	256.0	13.3
E-46 (500#IC Open 5000′)	155.6	
Total	778.9	19.6

Damage: 1.02 sq mi or 44 percent of city destroyed.

Damage to targets within built-up area—percent 90.25-383 Dai Nippon Celluloid Co. -20 percent destroyed.

For further target damage, refer to D/1 164, 5 Aug 1945.

Damage outside built-up area—3 small industrial areas just outside and west of built-up area were destroyed.

No previous missions. No bomb plot.

SUMITOMO LIGHT METAL INDUSTRY.—90.25-263A.

Mission 284. 24 July 1945, HE attack against this target using 4000-lb bombs. 77.5 percent of new damage resulted, with all main buildings either gutted or damaged. Total damage to date 90.5 percent. Total damage plus removal 96.4 percent.

Mission	No bombs	Tonnage	Type	Fusing	Percent	Percent 1000 percent of plot
189, 203 223	191	382	I.B. AN-M56 4000#LC	Inst. nose ND tail		No strike photos.
284	246	492	AN-M56 4000#LC	Inst. nose ND tail.	85 percent	55 percent.

OSAKA ARMY ARSENAL.—90.25-382

Mission 326. 14 August 1945, A/C of the 73rd Bomb Wing dropped 570 tons of 2000#GP and 273x1000#GP (136.5 tons): nose and tail, 0.025. 546 visible bursts plotted, 216 bursts or 26 percent within 1000′ of AP. Damage: 44.5 percent of original roof area. Total damage to plant, 64.3 percent.

Effects of Bombing.

1. Physical damage.

a. This information is covered individually under each substation and briefly in the tabulation in Exhibit A.

b. No effort was made to prepare a bomb plot of each station, but effects can be seen from photos in Exhibit B.

2. Production loss.

a. The tabulation in Exhibit A shows the load before and after the attacks.

b. No substitution or modification was necessary, as destruction of the area had destroyed the load simultaneously with the stations. Some substations will be permanently abolished because of the complete loss of load or plans for revamping the system.

c. (1) Refer to tabulation and individual substation description for general comments.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

3. Recuperability cycle.

a. No repairs had been made at any of the substations (not marked as abolished), but there has been some checking as to what items of the damaged equipment could be used. It is estimated that complete repairs can be made, based on the ability to secure required materials and skilled labor, in 6 months at the substations which will be retained.

b. In the tabulation, the great decrease in load will be noted, and thus there was no urgency to reattain capacity. (Exhibit A). It will also be noted that in no case was transformer capacity damaged to such an extent that it was the limiting factor in supplying the small load.

c. Temporary operation without the control board could be accomplished by manual operation of switch gear devices and, in some cases, by using temporary connections. It is also to be noted that incoming cable and switching did not suffer damage in any of the substations which will be retained.

4. Vulnerability.

Since most of these substations were badly damaged by fire, the impression may be given that substations are particularly vulnerable to incendiary bombing. Contrary to general practice, the Japanese used considerable wood in the construction of their substations, particularly the older ones, and these stations, located in the centers of densely populated

and highly inflammable districts, were subject to the same degree of fire damage as their surroundings. Also, there is considerable inflammable oil in substations which, once released and ignited, will do a great deal of damage. Substations are very vulnerable, as studies of these stations show, but are more subject to lasting damage through high explosive bombing than incendiary bombing.

Intelligence Check.

1. *a.* OSS Report did not list any of these substations except Ishizugawa.

b. The Air Objective Folder 90.25 for Osaka Area issued by the Office of the Assistant Chief of Air Staff, Intelligence, did not list these secondary substations.

c. JTG did not include any information on these secondary substations.

2. Records of raids in which these secondary substations were damaged are briefly covered in reports for the area, and it will be noted that nothing is included in these reports regarding damage to these secondary substations.

3. No mention was made in any damage assessment of recuperation or dispersal.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

These substations had been retained a long time beyond the logical point of replacement and badly needed simplification and modernization. Their locations were, in most cases, in crowded areas with highly combustible buildings immediately adjacent, and almost no protective measures were taken. Obviously, the loss of the area rendered the substations unimportant, but the destruction of the primary substations would also have made these stations useless.

EXHIBIT A—OSAKA SECONDARY SUBSTATIONS

Name of substation	Rated capacity KVA	Transformer equipment	Incoming lines and voltage	Outgoing lines and voltage	Load: Before attack KW and KW hrs[1]	Load: After attack KW and KW hrs[1]	Date and time of attack	Damage by	Principal damage[2]	Remarks
Nakamoto	5,000	9-1,000	2-10KV	16-3KV	1,380 (505,820)	0 0	14 Aug 45 11 AM	Direct bomb hit	Building partly destroyed; transformer bushing storage battery.	Serves domestic customers.
Sakurajima	17,500	5-3,500	3-20KV	15-3KV	11,500 (4,111,200)	0 0	24 July 45 10 AM	Direct hit IB and HE	Building completely destroyed; transformers all damaged.	Served industrial propeller and metal parts mfg.
Sakaigawa	7,000	3-3,500	3-10KV	15-3KV	4,340 (1,254,900)	1,000 (560,000)	14 Mar 45 3 AM	No direct hit; fire from IB, adjacent bldgs.	Building slightly damaged; switchboard completely destroyed.	Serves domestic and small power.
Dotombori	6,000	5-1,500	6-10KV	12-3KV	2,800 (494,600)	500 (280,000)	14 Mar 45 3 AM	IB direct hit.	Building slightly damaged; switchboard and control wiring destroyed; battery damaged.	Serves domestic and small power.
Ishizugawa	28,200	4-5,000 (70/20KV) 3-4,200 (70/3KV) 4-2,000 (20/3KV)	2-70KV	2-20KV 21-3KV	8,190 (5,024,010)	1,500 (700,000)	10 July 45 1 AM	IB direct hit.	All buildings destroyed by fire. Control switchboard destroyed and 3-KV switchgear severely damaged.	Primary supply to other substations. Served domestic and small power.
Yamatogawa	3,000	3-1,500	2-10KV	9-3KV	2,400 (687,600)	0 0	10 July 45 1 AM	IB hit all around. Fire did damage.	Building burned. Switchgear completely destroyed. Transformer damaged.	Serves domestic and small power. Will be abolished.

NOTES: 70-KV line overhead.
10 and 20-KV underground for large customers.
3-KV overhead.

NOTES: [1]KW hrs in parentheses—monthly average.
[2]More detailed damage given in description of each substation.
All substations owned and operated by Kansai Electric Supply Company.

Photo 1—Front view of Nakamoto substation

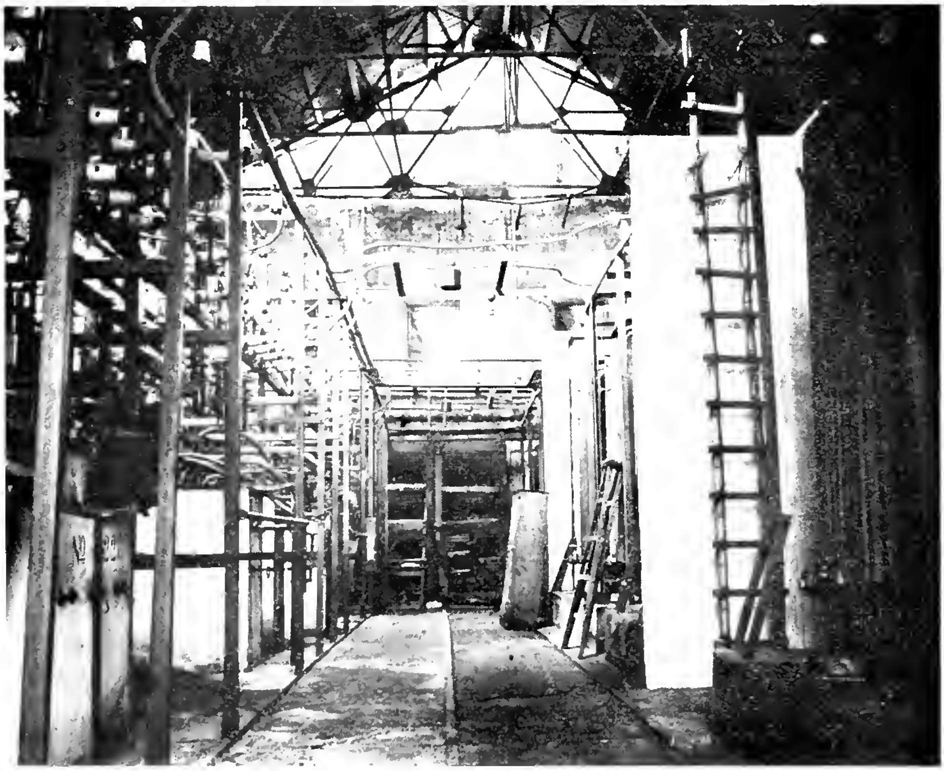

Photo 2—Nakamoto substation interior view ground floor—10KV switching structure at left and transformers in cells at right

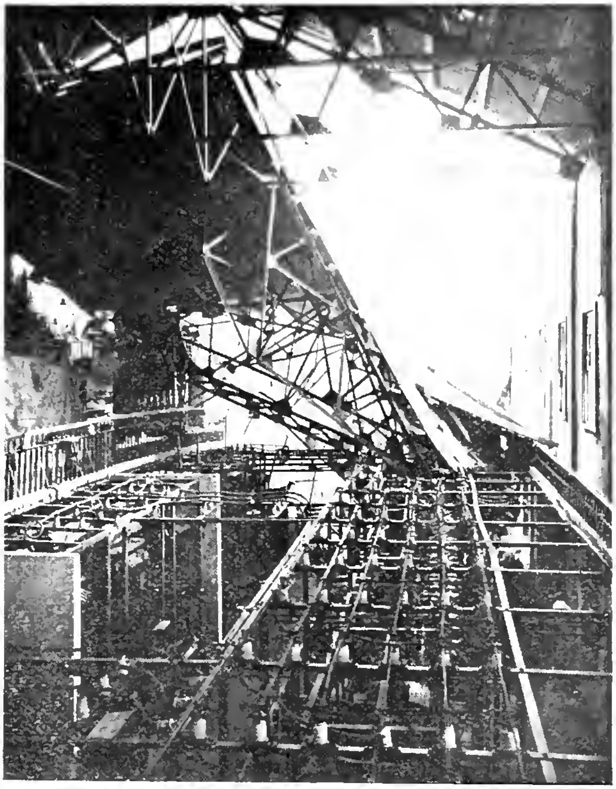

Photo 3—Nakamoto substation-view looking towards front of station taken just above mezzanine floor level

Photo 4—Sakurajima substation-view showing substation with outdoor transformers

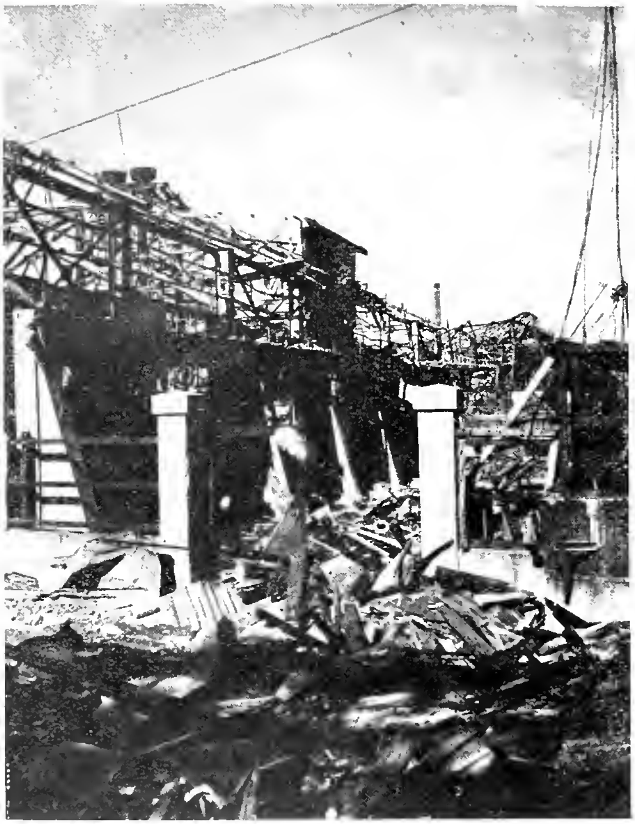

Photo 5—Sakurajima substation-view showing this substation at left and damaged industrial plant in background

Photo 6—View of damaged manufacturing building near Sakurajima substation

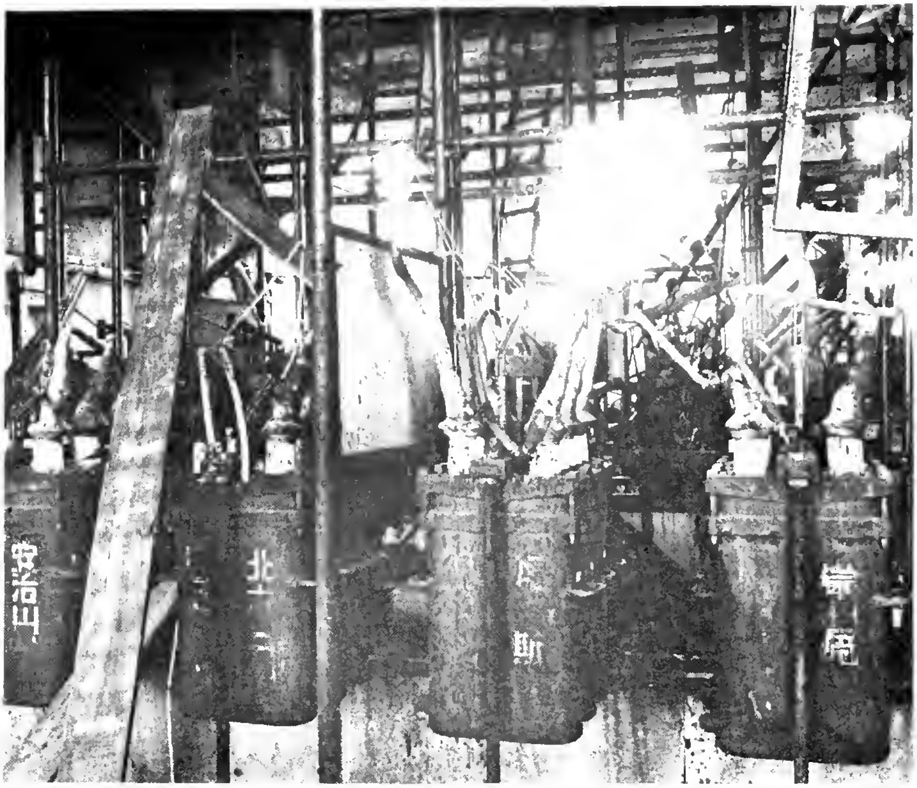

Photo 7—Sakaigawa substation, damaged 3-KV switching

Photo 8—Dotombori substation-view showing damaged control panels and control wiring, part in foreground removed

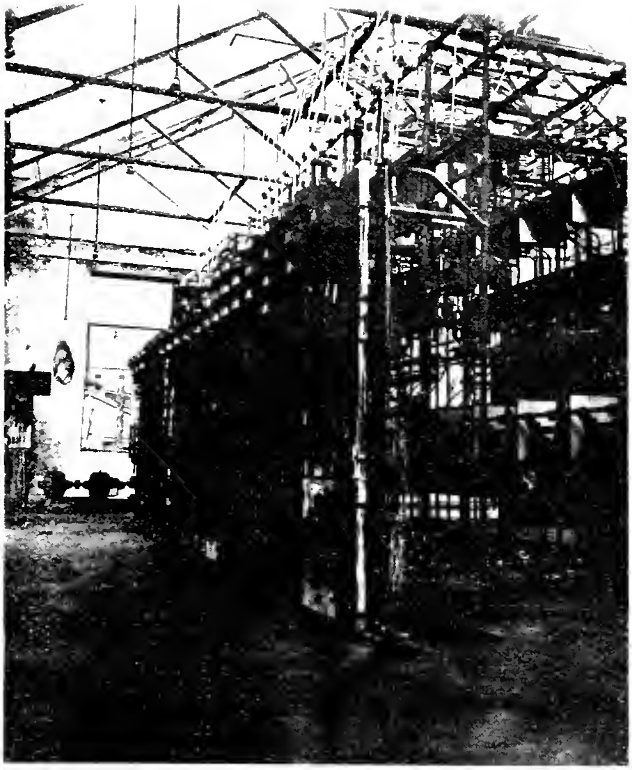

Photo 9—Yamatogawa substation-view showing main control panels, 3-KV switching in rear, and roof completely destroyed

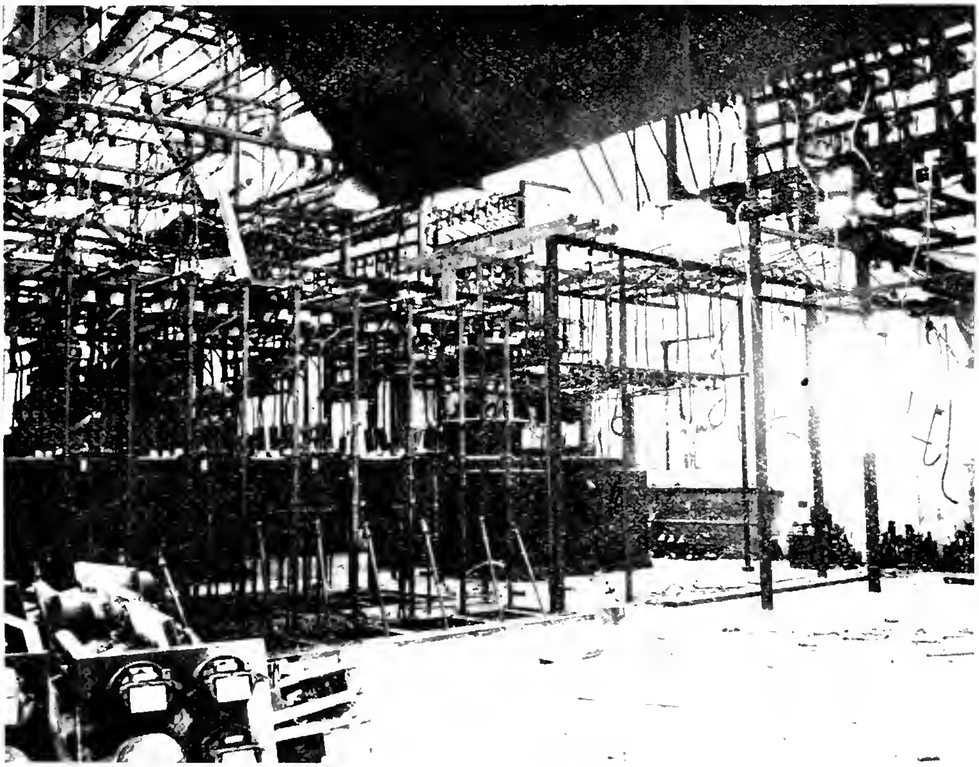

Photo 10—Ishizugawa substation-view showing location of damaged control board in front of damage d 3-KV switch gear

PLANT REPORT NUMBER 20

YAO SUBSTATION

OSAKA, JAPAN

DATE INSPECTED 29 OCTOBER 1945

Summary.

1. The Yao Substation is located at the town of Shiki in the Minami-Kawachi district of Osaka Prefecture, a short distance north of the Hanshin Airfield, on the Kansai main-line railway. It had a nominal capacity of 300,000 KVA, and is one of 3 primary substations in the Osaka-Amagasaki-Kobe Area. It was a very important and necessary substation in the process of transmission of electric current from hydro plants for utilization in this highly industrialized section.

2. This substation was never a primary target, but was damaged by two raids, one on 28 July and the other on 30 July 1945. Evidently these attacks were made by carrier planes of the U.S. Navy, using bombs, rockets, and machine guns, and thought to be by Mr. Eguchi, Master of substation, P-51 planes. There was a total of 14 hits by rockets or bombs which are definitely located, but doubt exists in some instances as to whether they were small bombs or rockets. No estimate of the number of individual machine gun bullet hits could be made, but they were great in number.

3. The principal damage was the destruction of 9 transformers, each 20,000 KVA, and the main control, which temporarily put the substation completely out of operation and indefinitely limited capacity to two-fifths of the original capacity. Production loss was not estimated since loss of load through previous area bombing had neutralized any economic effect. Temporary measures had been made to permit the use of the undamaged transformers, but no start had been made on replacement or repair to the damaged transformers.

4. The importance and location were correctly evaluated in intelligence data, although the size of the station as given was too low. No probable damage has been reported.

5. It is significant in this station to note that heavy and lasting damage can be done with a comparatively small amount of bombing effort. It is also especially significant that rockets and machine guns used in strafing could and did cause serious damage, although this type of attack is not recommended in preference to the use of HE bombs.

The Plant and Its Function In Enemy Economy.

1. The product of the plant and its importance in enemy economy.

The Yao Substation is one of 3 primary substations transforming the transmission line voltage of 154-KV from hydro-electric generating stations to 77-KV serving the network system in the Osaka-Amagasaki-Kobe Area for general distribution. It is the largest single substation in all Japan and very important in this highly industrial section.

2. Physical description of plant.

This substation is located at the town of Shiki in the Minami-Kawachi district of Osaka Prefecture, on the Kansai main-line railway, running north and a little east from the Hanshin airfield. The plant area is nearly rectangular, approximately 790 ft north-south, and 630 ft east-west, equaling approximately 11.5 acres. There is a reinforced concrete synchronous condenser and control building, approximately 245 ft long and 60 ft wide, which is located on the north side of the plant area. This building contains five 30,000-KVA, three-phase, 60-cycle, 11-KV, synchronous condensers, with space for 2 more together with all controls. All other equipment is located outdoors. The 154-KV section is located in the eastern half of the plant area. There are 4 incoming 154-KV lines, 2 entering the station from the north, identified as the Hokuriku Trunk Lines from Sasazu station near the city of Toyama, and 2 entering the station from the west, identified as the Kansai Trunk Lines from Inuyama substation, near Nagoya. There are 5 transformer banks, each consisting of three 20,000-KVA, 3-winding, single-phase, OISC transformers with conservation tanks, wound for primary voltage of 140 KV with suitable taps, for secondary of 77 KV, and for tertiary of 11 KV; the tertiary is connected to a synchronous condenser. Space is provided for 2 additional banks of transformers.

The 77-KV section is located in the west half of the plant area and nearly all of the ten 77-KV overhead lines leave the substation toward the west.

Outside the plant, in the same compound, are located various wooden buildings, used as offices, shops, and warehouses. In the northeast corner is located a

concrete basin for storage of cooling water for synchronous condensers.

3. The substation is owned and operated by the Japan Electric Generation and Transmission Company, and the following persons were interviewed:

Mr. S. Kadono, chf engr, Kinki Branch
Mr. S. Kaku, generation and transmission engr, Kinki Branch
Mr. M. Eguchi, master of Yao substation

4. The number of employees at this substation is 40, with no change from normal or war conditions. They operate on a basis of 2 shifts.

Attacks.

According to Mr. Eguchi, master of the station, there were 2 attacks by P-51 planes with rockets and machine guns. The first was on 28 July 1945 at 1315, and evidently the nearby airfield was the primary target, with the substation as a secondary target. The planes came from the north and circled the substation twice before attacking. The second raid was on 30 July 1945 by 8 planes in 2 formations of 4 each, which came from the northeast, circled the substation twice at comparatively low altitude, and then came in from the west for the attack.

No report of any mission by the Twentieth AF is available, and therefore it is believed that these planes were carrier planes of the U.S. Navy.

There is considerable doubt as to whether some of the hits were made by small general purpose bombs or by rockets. The station personnel feel certain that only rockets were used, but evidence indicates the possibility that some of the hits at least were with small bombs. However, it is equally certain that there were some rocket hits, and careful examination was made to see the effect of rockets on this type of installation.

Effects of Bombing.

1. Physical damage.

a. (1) The damage on 28 July 1945 is as follows:

One hit outside the synchronous condenser building, causing only minor damage.

One hit destroyed part of the outdoor neutral grounding resistor used on high tension side. Because of possible fragmentation from this rocket and the strafing of other transformers, the transformer oil was released and ignited; the resulting fire eventually enveloped 9 transformers together with structure and connections above the transformers, and four 140-KV oil circuit breakers. Exhibit A, photos No 1, 2, 3 and 4, give views of damaged transformers, photo 6 shows 140-KV oil circuit breaker, typical of damage to all 4 breakers, and photos No 4 and 5 show views of the damaged grounding resistors.

One hit directly on the 11-KV connections from transformer bank 5 to synchronous condensers. Damage was medium.

One hit was in the 77-KV switching structure. According to Mr. Eguchi, the rocket hit the concrete base of the oil circuit breaker, detonating and completely destroying the oil circuit breaker, instrument transformers, and the structure. The resulting oil fire caused further damage, including that to a small power transformer located to the south. Exhibit A, photo 7, shows damage which would appear to be caused by an HE bomb.

One hit was on the main building, causing minor damage only. Further damage during this raid was the incoming line breaker bushing and tank, 2 poles of the adjacent disconnecting switch, tie breaker tank, and the bushing of the 140-KV, oil, circuit breaker for number 4 transformer bank. Other damage to the 140-KV structure was mostly to the insulators of the bus supports and the disconnecting switches. As a result of the strafing, a great many oil circuit breakers, potential transformers, and lightning arresters suffered damage, and a large number of insulators were broken.

b. The damage on 30 July 1945 was as follows:

Two hits were outside of the plant area proper, damage was minor.

One hit was on 77 KV structure—minor damage; parts damaged, such as insulator connections and structure.

One hit was in the 140-KV section causing no damage.

One hit glanced off a transformer bushing and landed at a point nearby, damaging the bushing slightly.

Two hits caused only minor damage.

Two hits were on the control building. It is quite certain that these were rockets. One of the 2 rockets went through the wall above the main control floor, starting a fire which completely destroyed the control desk and auxiliary panels. The other went through under the main floor, causing a fire which destroyed the control cable. At the time of inspection, damage to walls had been repaired. Exhibit A, photo 8, show half of control desk repaired.

In Exhibit A, photo 2, some vertical rods can be seen at the extreme right of the picture, and in photo No 3 this same type of rod can be seen in the foreground. These are for the concrete walls, being constructed across the transfer track from the trans-

formers in front of the 154-KV, oil, circuit breakers. These 7-ft walls had been finished opposite transformer banks nos 4 and 5, but not opposite the others. These walls had been damaged slightly. Other protective measures were shelters for personnel at various points.

2. Production loss.

a. This is one of 3 primary step-down substations supplying the Osaka-Amagasaki-Kobe industrial area; this area was severely damaged and practically destroyed before this station was damaged. Therefore, the load was so small that it was possible to shift it to the other substations. However, had the load been its normal amount of about 200,000 KW before the raids, there would have been considerable difficulty in handling it, especially if the other 2 stations had been damaged simultaneously. At the time of this inspection, the load was approximately 50,000 KW, which was easily handled through one of the 2 remaining 60,000-KVA transformer banks.

b. There is no substitute for damaged or destroyed transformers, but modification is sometimes possible. Some relief could have been obtained through operation of the steam plants in this area though coal was at a premium. Adjacent substations could have handled at least part of the load, or possibly the incoming line voltage could have been changed at some previous point to 77-KV, and the temporary jumpers utilized around this station. This, however, would have been at a sacrifice of a large amount of line capacity, especially since the synchronous condensers would have been inoperative. In the event of destruction of the other primary substation and steam plants in this area, no appreciable modification would have been possible.

c. Causes for loss of production.

(1) The temporary loss of the entire station was due to loss of the main control room by fire. The loss of three-fifths of the station capacity was due to the destruction of the 3 banks of transformers through bombing and resulting fire.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss of production was caused through absenteeism or unusual inefficiency.

(5) No loss was caused by loss of any other essentials.

3. Recuperability cycle.

The complete substation was out of commission for only a short period during which the other 2 primary substations carried the load. As the main control, including battery, was destroyed, a small auxiliary plant was installed to furnish power for control and operation of the oil circuit breakers so that the 2 remaining banks of transformers could be used. At the time of inspection part of the control room had been temporarily repaired (Exhibit B, photo 8), but none of the damaged transformers of the 3 banks had been repaired or even untanked for checking to determine whether the core and coils had been totally destroyed by the transformer oil fire. It is believed that these will have to be completely replaced, and it is estimated that at least one year will be required to place the entire station back in operation.

4. Vulnerability.

The vulnerability of this substation is fully shown by the heavy damage caused by a comparatively small amount of bombing. The results of rockets and strafing are also clearly demonstrated, although a more desirable result will be obtained from the use of bombs against the sort of highly concentrated, fragile equipment that is found in all substations.

Intelligence Check.

1. *a.* OSS reports in general correctly identified and evaluated this substation, but gave the capacity of the substation as 264,000 KVA.

b. The Air Objective Folder 90.25 for Osaka-Amagasaki-Kobe Area, issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this substation as target 1631, correctly located it on maps, and evaluated its importance, but did not give plot plan or photographic information.

c. JTG information was very meager, although aerial photographic information located the target correctly.

2. Records of raids in which this substation was damaged are not available, as no report can be located. Evidently the information given by Mr. Eguchi, master of the substation, was correct, and it is believed that the raids were by carrier planes of the United States Navy. No damage assessment report is on file.

3. No reports of assessment of recuperation or dispersal are on file.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

This substation had been well maintained and the plant personnel were doing very excellent work getting the station control and other parts back into operation.

While this station demonstrated fully the comparative ease with which substations can be heavily damaged and rendered inoperative for long periods of time, it also shows that there is no economic effect unless other stations or facilities within the same area are simultaneously damaged. In this case, the loss of load had already been accomplished through destruction of the industry and cities in the area served; therefore, no results were obtained in this case. However, assuming that the load had existed at the time of damage, most of the loss could still have been overcome. Recommendations covering the destruction of substations and its effects on electric power service are fully covered in the final industry report.

EXHIBIT A

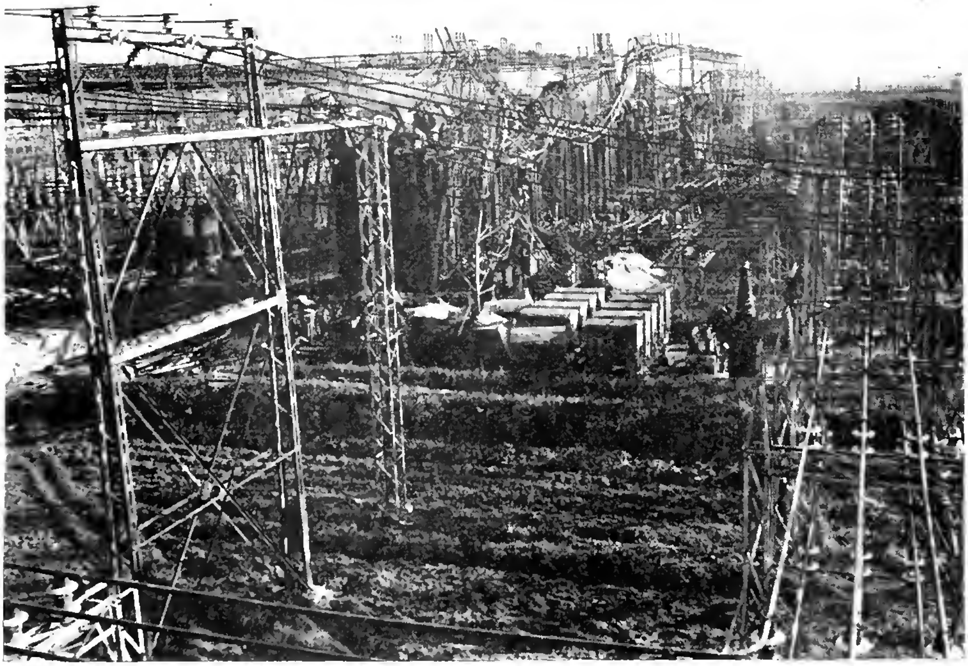

Photo 1—General view of main damaged section, looking south from control room

Photo 2—Closer view of damage to transformers and structure, looking north—synchronous condenser building in background

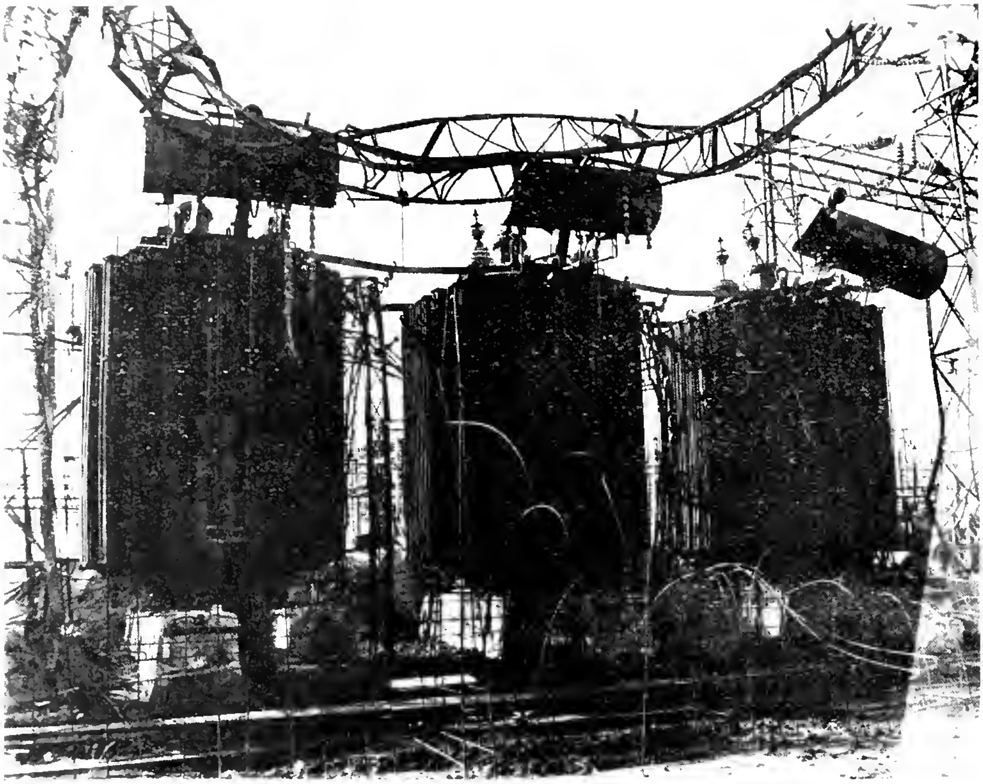

Photo 3—Another view of nearest bank shown in photo 2—reinforcing rods for protective wall in foreground

Photo 4—Another view of damaged transformers and structure, with outdoor grounding resistors in foreground

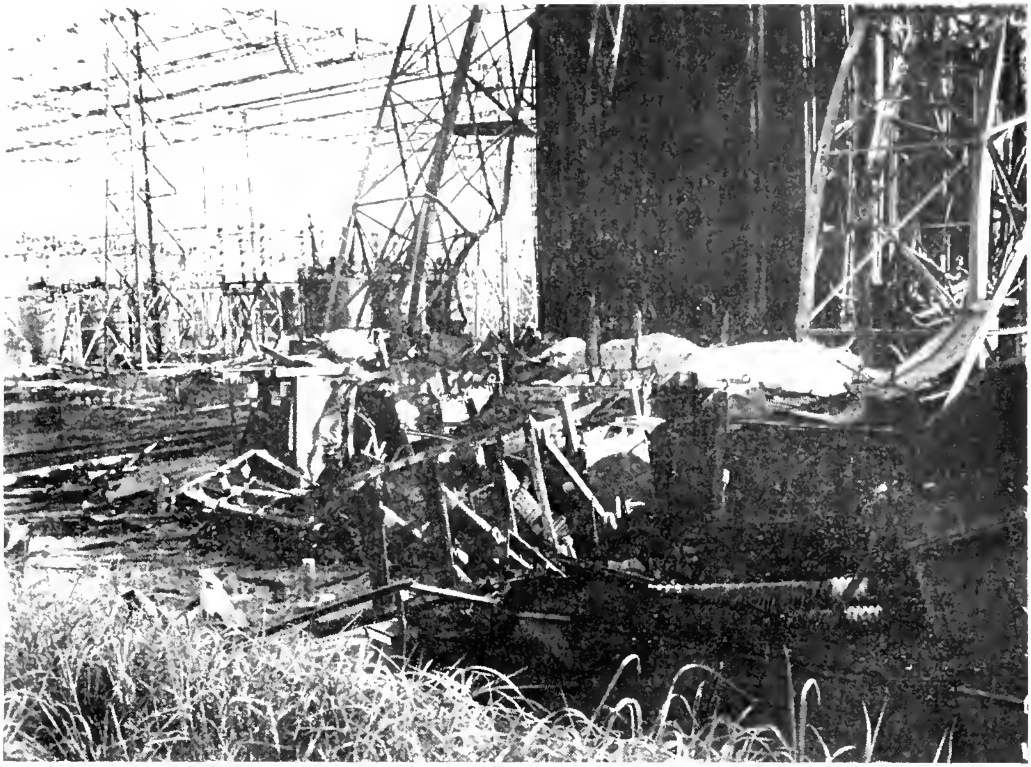

Photo 5—Closer view of damaged grounding resistors

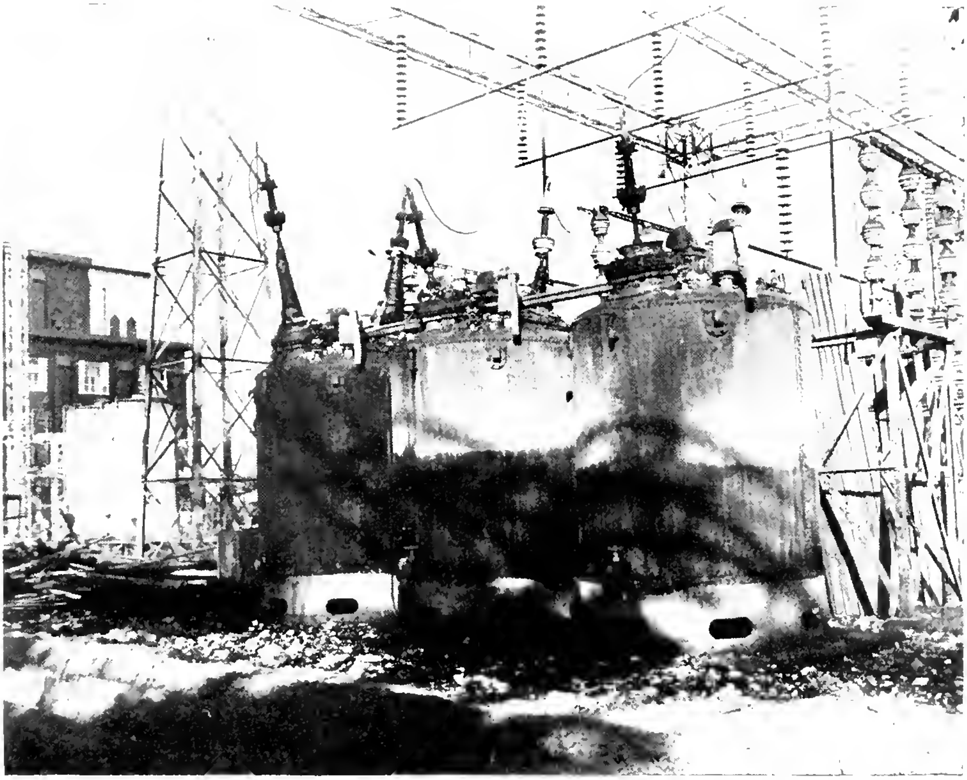

Photo 6—View showing damaged 140-KV oil circuit breaker for transformer bank No 1, with east end of synchronous condenser building at left

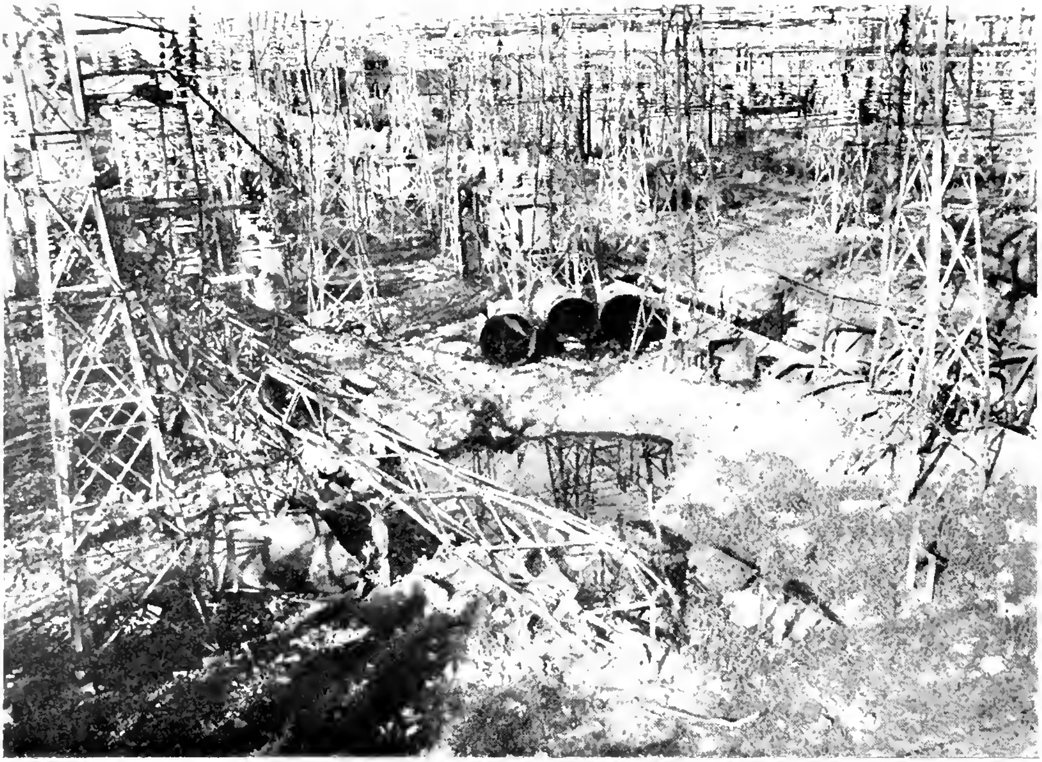

Photo 7—View showing damage done by rocket hit in 77-KV switching section

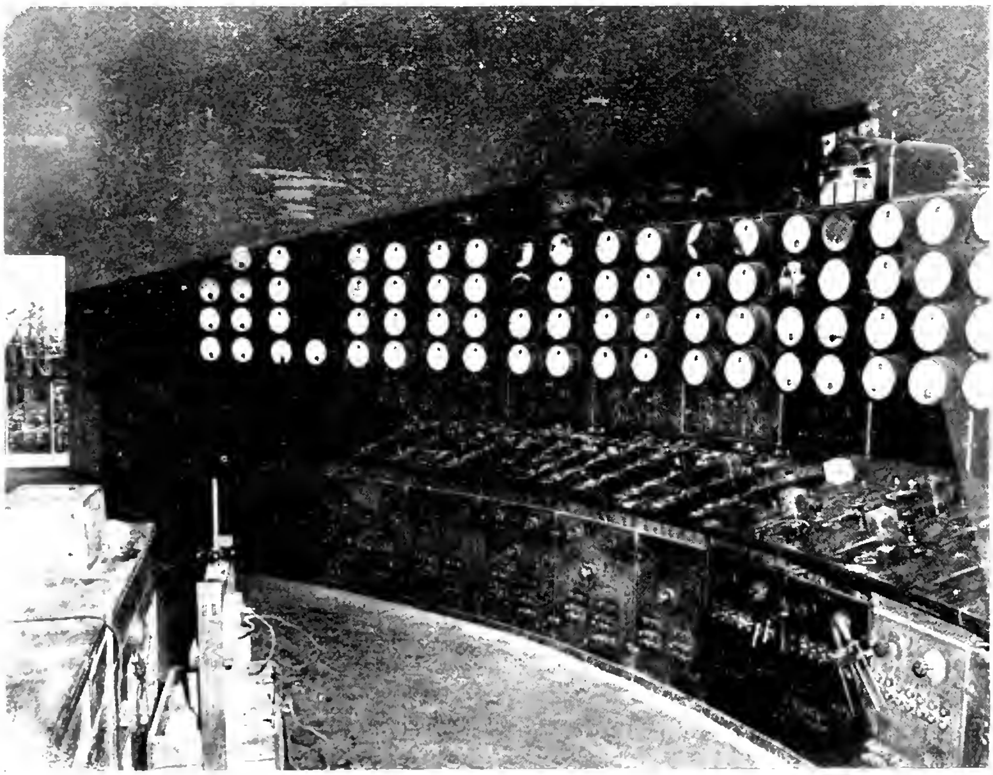

Photo 8—View of partially repaired control desk

PLANT REPORT NUMBER 21

SHIOJIRI SUBSTATION

NEAR MATSUMOTO, CENTRAL HONSHU, JAPAN

DATE INSPECTED 4 NOVEMBER 1945

Summary.

1. The Shiojiri Substation is located in central Honshu near the city of Matsumoto. It had a transformer capacity of 60,000 KVA; however, since an important function of the station was to act as a switching and control point for incoming and outgoing lines of the same voltage not requiring transformation, the capacity of transformers does not indicate its true size. The station is a complete outdoor type. During the 3 war years, the output of the station was approximately 100 million KWH per annum, not an appreciable quantity in the total of all of Japan. The principal function of the station was to act as a central collection point for energy from 3 separate groups of hydro generating stations, and to control, switch, and dispatch this energy to several different outgoing transmission lines mainly going to the Tokyo Area. Where such energy was received at 77 KV, it was transformed to 154 KV. In addition, this station supplied energy directly to a large industrial plant located nearby.

2. There were no attacks on, or war damage to, the station.

3. There was no physical damage nor any production loss. Therefore, no recuperation cycle was established. It was vulnerable to attack as are all substations, though its location made it somewhat inaccessible. In the event of damage or destruction, means of bypassing the station could have been put in effect, and thereby much of the loss could have been overcome, and thus any economic result would have been neutralized.

4. This station was not mentioned in any intelligence data.

5. The value of the study of this station lies in the fact that any effort that might have been expended for its destruction would have been futile, since means were available to overcome to a large extent the difficulties that would have been caused by its destruction. Therefore, it can be seen that, in making any plans for elimination of the electric system of Japan, the effects to be attained by destruction of substations must be based on careful consideration of the functions of each station and of the existence of means by which the loss can be overcome.

The Plant and Its Function In Enemy Economy.

1. The product of the plant and its importance in enemy economy.

This is a very important switching and transformer station in the transmission system of the Japan Electric Generation and Transmission Company. Its principal function is to act as a switching and centralized control point for incoming 154-KV transmission lines from various groups of hydro stations in the central Honshu mountainous area, and to retransmit to lines going to Tokyo or Nagoya. It also receives current from one group of hydro stations at 77 KV, transforms to 154 KV, and retransmits. This station also serves one large industrial customer. This is contrary to usual practice as the Japan Electric Generation and Transmission Company generally supplies only the various distributing companies. This customer is the Showa Denko Company's carborundum factory, located nearby, and it is served directly by a 77-KV line with a maximum load of 15,000 KW. The total energy passed through this station was approximately 100 million KWH annually, but the monthly load varied in accordance with the hydro seasons.

2. Physical description of plant.

a. This substation is located at the village of Hirooka, near the city of Matsumoto in Nagano Prefecture, central Honshu, and was put in operation in November of 1924. The area covered is very irregular in shape, but generally is somewhat formed like an L and covers about 5½ acres. Except for buildings to house the office, control room, repair shops and warehouse, the station is a complete outdoor type. (Exhibit A, photo 1). The following incoming or outgoing lines are connected to the station:

- Takasegawa Line 154-KV, 2 circuit from hydro plants on the Takase River.
- Azusagawa Line 154-KV, 2 circuit from hydro plants on the Azusa River.
- Hirao Line 77-KV, 2 circuit from hydro plants in the Hirao area.
- Koshin Line 154-KV, 2 circuit to Asahi substation at Tokyo.
- Matsushima Line 154-KV, 2 circuit to

Matsushima switching station from which point the Tenryu line goes to Nisshin substation in Nagoya and the Tsunajima line goes to various substations at Tokyo.

Showa Denko Line 77-KV, 1 circuit to Showa Denko Co. carborundum plant.

The transformer capacity of the station is 60,000 KVA consisting of 2 banks with 3 single phase transformers, each rated 10,000 KVA 154/77-KV, and there is one spare transformer (Exhibit A, photo 2). There is a total of eleven 154-KV and seven 77-KV oil circuit breakers (Exhibit A, photo 3), together with the usual bussing, bus structures, station transformers, potential and current transformers, control and instrument boards, oil tanks, cooling pond, and other equipment (Exhibit A, photo 4).

3. The station is owned by the Japan Electric Generation and Transmission Company, and information was furnished by Saburo Iwamune, station master.

4. The number of workers usually employed in the station is 14, which number did not vary throughout the war.

Attacks.

None.

Effects of Bombing.

1. Physical damage.
   None.
2. Production loss.
   None.
3. Recuperability cycle.
   Not determined as there was no damage.
4. Vulnerability.

a. This station is as susceptible to damage as are all substations. It was located in central Honshu some distance from the coast, and therefore was not very accessible. Though located in a mountainous section of Japan, the station itself was situated in an area of a high plain and could have been easily located and approached.

b. Had this station been destroyed, certain methods could have been adopted to counteract the effects. The 2 incoming and 2 outgoing 154-KV lines could all have been connected together by means of temporary by-pass jumpers around the station, or each of the incoming lines could have been connected to one of the outgoing lines. Control would have been lost, but some semblance of operation would have been secured. The real bottleneck would have been the fact that means to transform, and thus utilize the energy coming in on the 77-KV line from that group of hydro plants would have been destroyed, and, thus, this power would have been lost. In addition, the means to serve the Showa Denko Industrial Plant would have been curtailed, but it might have been possible temporarily to connect this feeder line to the incoming 77-KV line and thus utilize at least part of this hydro power and at the same time provide service to the industrial plant. Thus, the bottlenecks caused by destruction of this station could largely have been overcome, and, therefore, there would have been no large beneficial results attained unless other substations were simultaneously destroyed.

Intelligence Check.

1. This station was not listed in any intelligence data.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

This station was well constructed and operated. The importance was definitely established, but, likewise, the means of overcoming any damage or destruction were so easy and could be effected so quickly that it appears that it would have been quite futile to expend any effort to eliminate the station.

Photo 1—General view of station

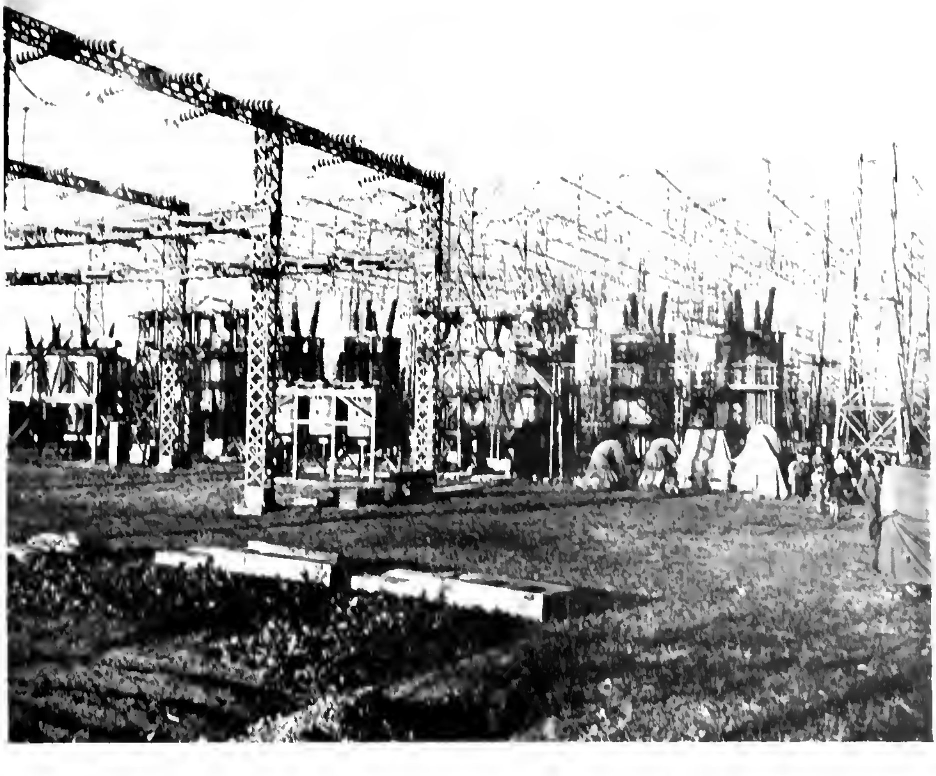

Photo 2—Portion of 154-KV section and 10,000 KVA 154/77 KV transformers

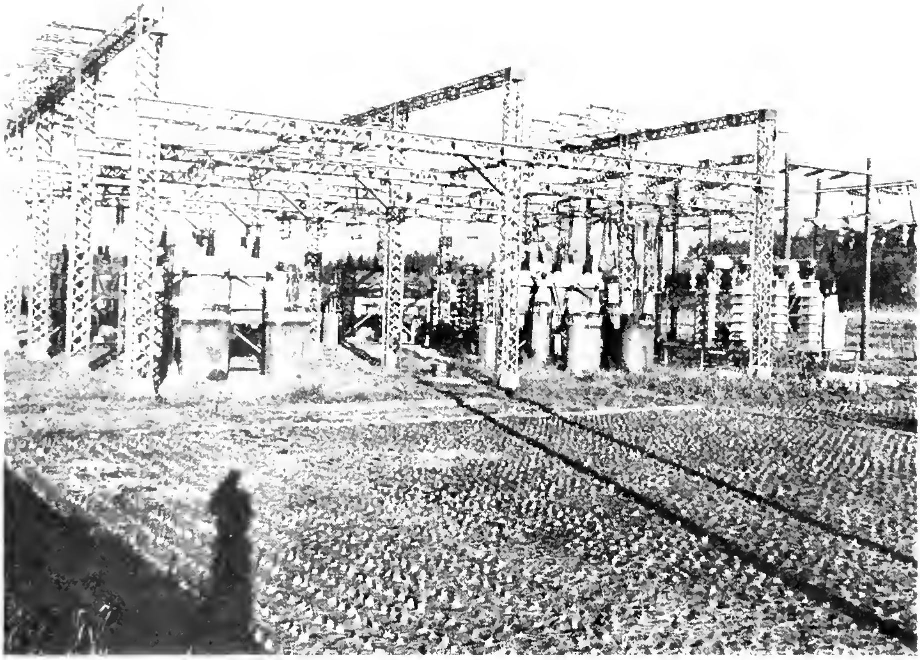

Photo 3—Portion of 77-KV section showing oil circuit breakers

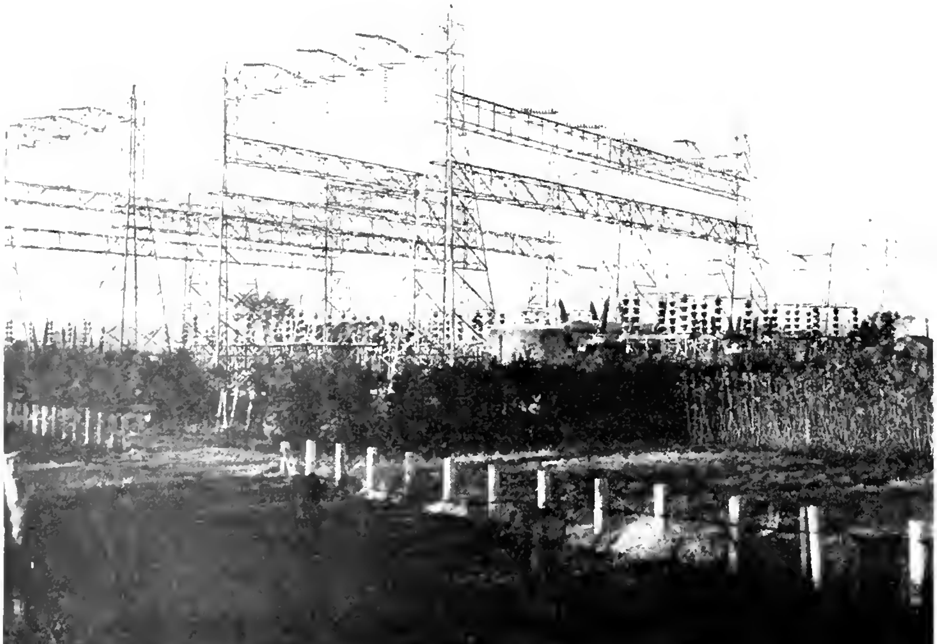

Photo 4—54-KV section showing outgoing 154 KV lines

PLANT REPORT NUMBER 22

KAWASAKI SUBSTATION

KAWASAKI (NEAR TOKYO) JAPAN

DATE INSPECTED 19 OCTOBER 1945

Summary.

1. The Kawasaki Substation is located about a mile west of the Kawaski Power Plant of the Imperial Government Railways in the city of Kawasaki, between Tokyo and Yokohama, and had a nominal capacity of 210,000 KVA. It is one of the important primary substations in the Tokyo-Kawasaki-Yokohama Area, in the supply of electric energy from distant hydro stations to the network system serving this large industrial and populated section.

2. This substation was never a primary target but was damaged in the raid of 15/16 April 1945 on the Kawasaki urban area by the Twentieth AF. During this raid approximately 1,200 tons of incendiary bombs were dropped, and 8 bombs fell within the plant area.

3. The principal damage was practically complete destruction of one bank of 60,000 KVA in transformers and of the station control cables. Because of damage elsewhere on the incoming lines, the substation was not in operation during the raid. The only attempt at recuperation that was made was the repair of the control cables and inspection of the transformers. The vulnerability of substations is fully shown because of the heavy destruction caused by relatively few bomb strikes, all of which were incendiaries.

4. The size, importance, and location, as well as probable damage, had been reasonably correctly, but very briefly, evaluated in intelligence data.

5. This station was an open-air type, yet was seriously damaged as the result of incendiary bombs. The direct hit on the large transformer by one bomb burned a hole in the radiator, caused an oil leak, and then set the oil on fire; this in turn almost totally destroyed 5 transformers. This was, however, a very unusual incident. Had the position of the bomb hit been even slightly different, such as a near miss, no serious damage would have occurred. On the other hand, an HE bomb, in either a direct hit or near miss, would have caused heavy destruction. Therefore, the conclusion should not be made that IBs are the proper weapon for use against substations.

The Plant and Its Function In Enemy Economy.

1. The Kawasaki Substation was one of the important primary substations in the highly industrialized and densely populated area of Tokyo, Kawasaki and Yokohama. Its principal function was to receive current from several groups of hydro plants, located in the mountainous areas of central Honshu, by means of several incoming transmission lines of 154-KV, transform to 66-KV, and to dispatch by outgoing lines to the network system for general distribution.

2. This substation is located at 1173 Yanagi district, Kawasaki City, near Tokyo. It is adjacent to the Tokyo Shibaura Engineering Works Plant No 2, and about a mile west by south from the Kawasaki power station of the Imperial Government Railways. Also, about a mile NW is located the Tokyo Shibaura Engineering Works Plant No 1. The plant area is irregular in shape and has a total acreage of approximately 7.5 acres. The control room and offices are contained in a concrete building approximately in the center of the plant area, but otherwise all equipment is of the outdoor type. There are 6 incoming lines, 2 of which are the Tashiro, and the other 2 are the Kitatama transmission lines.

3. There are 4 banks of main transformers with a total capacity of 210,000 KVA. Two of the banks each consist of three 20,000-KVA, single-phase transformers OISC with primary winding for 140-KV, secondary 66-KV, and tertiary of 22-KV. One of these banks was installed in April 1944, and the other in April 1945. The other 2 banks each consist of three 15,000 KVA, single-phase transformers OISC with primary winding for 140-KV, secondary 66-KV, and tertiary winding of 22-KV. Both of these banks were installed in 1926.

The 154-KV section of the station is west of the control building and contains all the transformer banks, together with necessary oil circuit breakers, bus structures, and bussing. Switching is arranged so that the transformers can be operated in parallel or single on all windings by means of a double bus, each bus being sectionalized.

The 66-KV section is located to the south of the control building and contains the switching equipment for the secondary side of the main transformers and the six outgoing overhead lines leaving the station to the south.

The 22-KV section is located to the east of the control building and contains the switching for the tertiary side of the main transformers and 14 outgoing lines, most of which are underground. Adjacent to this section is located 20,000 KVA in outdoor static condensers made up of 4 sections of 5,000-KVA each; each section is, in turn, made up of 250-KVA units.

In the control building is located the dispatching office for this substation as well as the Keinan, Osaki, and Totsuka substations.

4. All 154 and 66-KV portions of the station are owned by the Japan Electric Generation and Transmission Company, while the 22-KV portion is owned by the Kanto Electric Supply Company, the distributing organization for this area.

5. This substation normally used 15 men on the basis of 2 shifts, but at present only 9 men are being used. There are 2 operators per shift, and the rest of the employees perform general maintenance and repair work.

Attacks.

There were no specific attacks on this substation; however, it was damaged during one raid on 15/16 April 1945 between 2200 and 0100, during an attack on the Kawasaki urban area, mission No 68 of the Twentieth AF. Two hundred and nineteen A/C of the 313th, 314th, and 315th Wings dropped approximately 1,200 tons of incendiary bombs from a height of 8,000 ft with clear to 3/10 weather. According to plant personnel, there were 8 bombs that fell in the substation area.

Effects of Bombing.

1. Physical damage was as follows:

a. One direct hit by an incendiary bomb on the middle transformer of one bank of 60,000-KVA transformers. (Exhibit A, photo 2) This burned a hole in the radiator of the transformer, causing the oil to leak and setting it on fire. The resulting transformer oil fire enveloped both adjacent transformers in this bank (Exhibit A, photos 3 and 4), seriously damaging all 3 transformers as well as the overhead structure and connections. In Exhibit A, photo 1, it can be seen that the resultant heat buckled the upright column of the structure to the left of this bank of transformers. This photograph does not show the transformers in the position they were in when the damage took place. There were originally 2 banks of 3 transformers in each bank, all placed in a single row and numbered 1 through 6 from left to right. The damaged bank was composed of transformers 4, 5, and 6, which occupied the space between the upright structures at the right of the photograph. Following the damage, the transformer locations were changed and spread out in order to provide a safeguard against a recurrence of similar damage. The good transformers were put in positions 1, 3, and 5 and the damaged transformers between them in positions 2, 4, and 6.

One bomb hit near the control building, burning a wooden extension as well as burning the contents of the south end of the concrete control building.

One bomb hit near the wooden extension of the control building, burning out the control cable in a concrete duct with a wooden cover at 2 points about 20 ft apart.

One bomb hit near the base of a tower carrying 66-KV connections, doing no damage to the tower but damaging a control cable.

One bomb hit near the static condensers, burning a hole in one 250-KVA unit.

One bomb hit directly on the warehouse—the resultant fire completely destroyed it.

One bomb hit directly on the forge shop—the resultant fire completely destroyed it.

One bomb hit on a 20-KV outdoor structure, damaging insulators and bending connections.

At the time of the raid, this station was not in operation, since the lines were out because of bomb damage elsewhere. Dugout shelters were provided for employees, and blast walls, made up of wooden sides with the base very much wider than the top and earth filled, were installed in front of banks of transformers. The walls were located on the near side of the pits in front of the transformers, and had been completely removed at the time of inspection. Similar walls were installed for protection of the 160-KV breakers. Fire protection was inadequate to deal with a transformer oil fire of such magnitude as occurred at this station.

b. Information was supplied by Mr. K. Wako, chief of the station, and by personal inspection.

2. Production loss.

a. As this is one of several primary substations supplying the industrial and residential areas which were severely bombed during the raid when this station was damaged, and also at other dates, the load was down to a practically negligible quantity. Before the raid it was 30,000 KW, and, at the time of inspection, it was only 10,000 KW.

b. No substitution was needed as there was excess capacity in undamaged portions.

c. (1) Only the part damaged was made inoperative.

(2) No production was lost through diversion of labor, material, or machine facilities.

(3) No loss of production was caused through protective measures.

(4) No loss was caused through absenteeism or unusual inefficiency.

(5) A loss of load was caused by bombing of industrial and residential areas.

4. Recuperability cycle.

The station was shut down one day and then placed back in temporary service by operating the various oil circuit breakers by hand, without any meter readings. It took one week to repair the control cables. The damaged transformers have been examined, and it was found that the core and coils of one transformer could be used, but that the others could not be. It is estimated that it would take 2 years to get new transformers. The undamaged portion of the plant is available with 150,000 KVA capacity.

4. Vulnerability.

The vulnerability of substations is fully covered in the final report, which is applicable to this substation.

Intelligence Check.

1. *a.* OSS reports in general correctly identified and evaluated this substation.

b. The Air Objective Folder 90.17 for the Tokyo Area, issued by the Office of Assistant Chief of Air Staff, Intelligence, listed this substation as target 105, correctly located it on maps, and evaluated its importance, but did not give a plot plan and photographic information.

c. JTG information was very meager, though aerial photographic information located the target correctly and the size of the plot plan was approximately correct.

2. Records of raid in which this substation was damaged are covered in the Report on Mission No 68 on the Kawasaki urban area. Damage Assessment Report No 47 covering this raid was practically correct.

3. No mention was made in any damage assessments of recuperation or dispersal.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

This substation contained a section for 110-KV which was not used; this section was neither diverted to 66-KV use, nor dismantled for scrap use when they were in such need of material. General upkeep of the yard was poor; however, the equipment appeared to be well maintained. There was a large over-capacity for the load demand.

EXHIBIT A

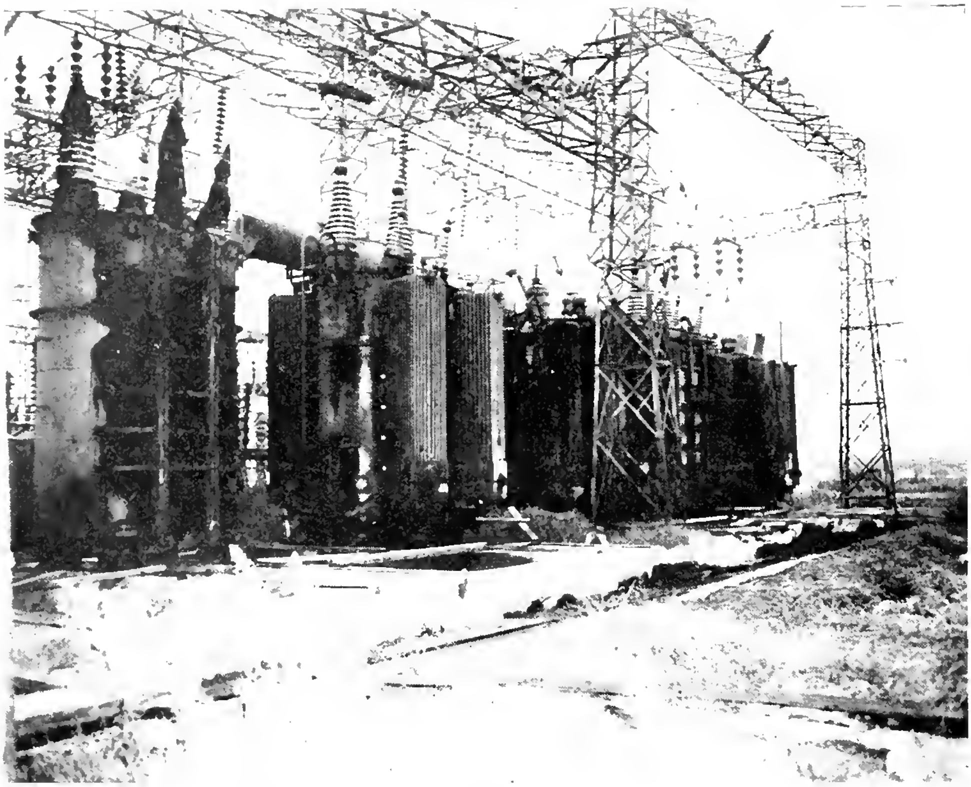

Photo 1—60,000-KVA transformer banks, showing transformer positions from left to right, numbered 2 through 6 (No 1 transformer not shown on left). Damaged transformers were originally in positions 1, 5 and 6; now occupy positions 2, 4, and 6

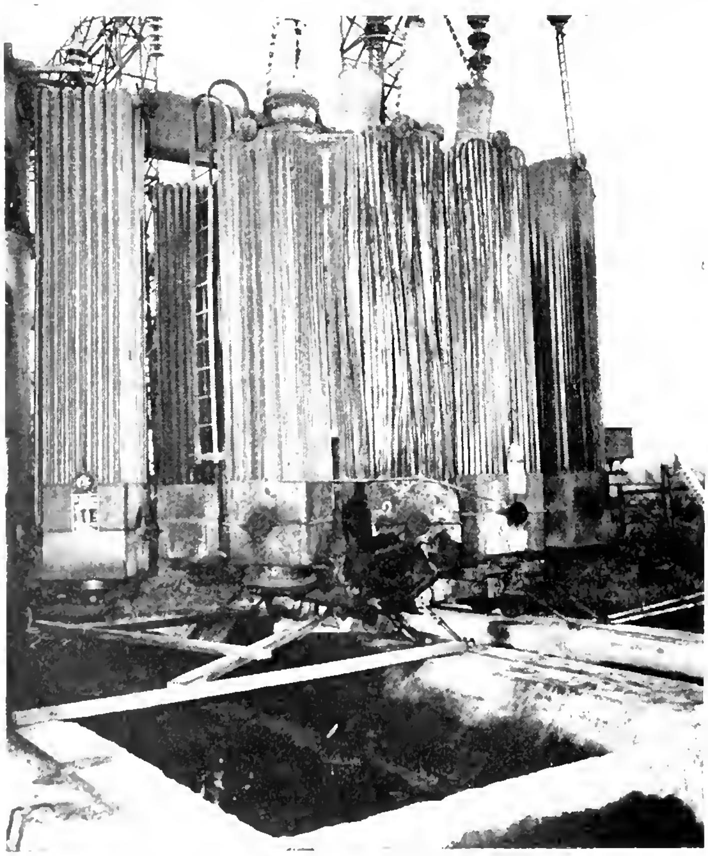

Photo 2—View showing damaged transformer in original position No 6

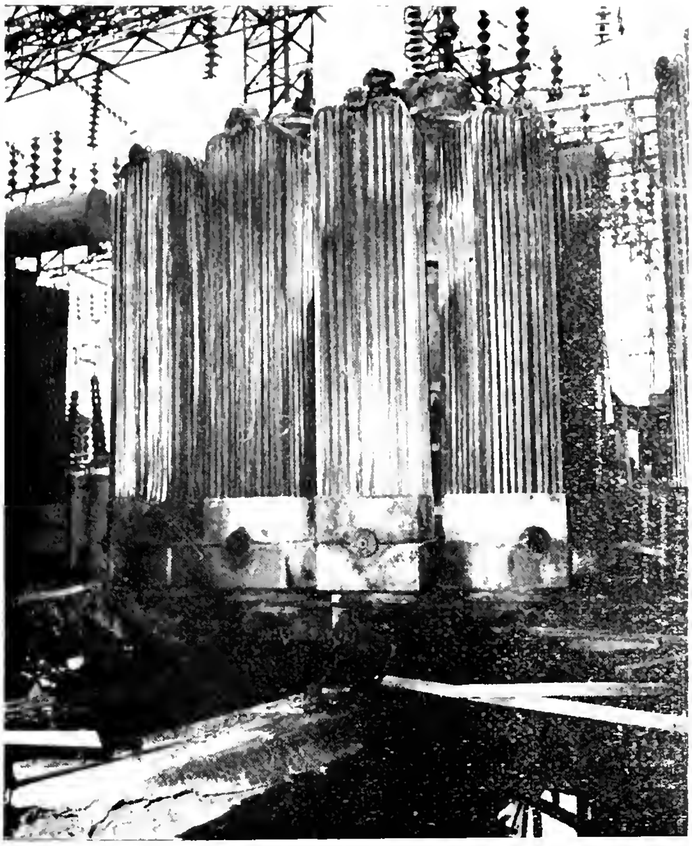

Photo 3—View showing damaged transformer in original position No 4, photo No 1

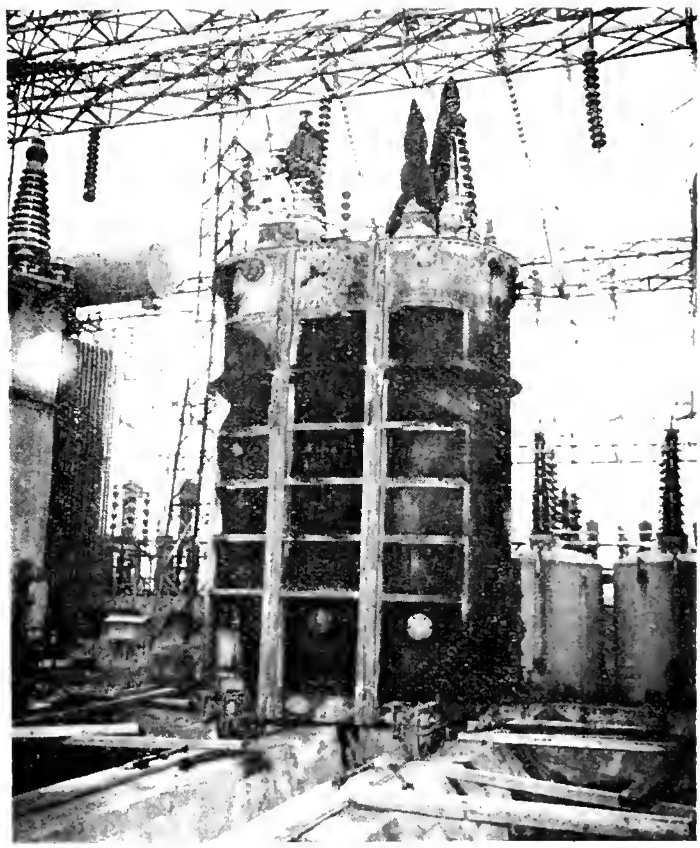

Photo 4—View showing damaged transformer with radiators removed, originally occupying position No 5, photo No 1

PLANT REPORT NUMBER 23
TOKYO PRIMARY SUBSTATIONS
TOKYO, JAPAN
DATES INSPECTED 27 OCTOBER—9 NOVEMBER 1945

Summary.

1. This report covers a group of 6 primary substations located in the vicinity of Tokyo and serving the highly important industrialized and populated area of Tokyo, Kawasaki, and Yokohama. These 6 substations have a total transformer capacity of 864,000 KVA, and while they do not constitute all the primary substations serving this area, their combined capacity represents approximately 55 percent of the total. These stations are all outdoor type, with reinforced concrete buildings to house the control room, offices, repair shops, and other similar installations. In addition to transformers, switching equipment, and other necessary facilities, all the stations are equipped with rotary and/or static condensers. The principal function of these stations is to receive, transform, and dispatch current from the hydro power stations in central and northern Honshu to the 66-KV network supplying this area.

2. There were no primary attacks on these stations, but slight damage was inflicted on 2 of the stations during area raids. One was on 26 May 1945 when about 200 IBs fell on the Kameido stations, and the other was on 13 July 1945 when 7 HE bombs fell on the Hatogaya station.

3. There was no appreciable damage in either raid, and no interruption in service occurred. In particular, it should be noted that a large number of incendiaries fell on the Kameido station with no effect, thus showing the futility of this type of bomb against modern substations. While this report covers only about half the primary substations in this area, a study of the damage done to all the primary substations (shown in the Electric Power Industry Report) reveals that less than 8 percent of the total capacity of the entire area was eliminated by either direct or indirect damage from bombing. Production loss was nil and recuperation from the minor damage was immediate. However, had there been substantial damage, recuperation would have been difficult and lengthy. Since there was practically no damage, actual vulnerability was not demonstrated, but these substations are as vulnerable and susceptible to damage as all such installations are. However, these substations are all interconnected, both primary and secondary, by means of a loop system, are served from the hydro plants through various transmission lines and routes, and all of them have over-capacity. Therefore, the destruction of any one, or even a few, could be quickly overcome by by-passing the station and/or re-routing transmission. Thus, while individually they are vulnerable to damage, definite, serious economic effects only result from the destruction of all or a majority of them.

4. Pre-raid intelligence data was practically nil.

5. The most significant evaluation of this study is the revealed fact that there were a multiplicity of facilities and over-capacity, which would act as a safeguard against economic consequences from the destruction of any single station. This was not an intentional war precaution, but rather the result of duplicate facilities having been installed by several different operating companies prior to the consolidation into the one company, namely, the Japan Electric Generation and Transmission Company. The over-capacity was largely due to a tendency of the Japanese to install facilities capable of handling possible future demands too vaguely estimated to constitute good engineering or economic practice. Despite these facts, it has been conclusively shown that the destruction of a majority of these stations, plus the main steam plants in the area, would have produced a definite collapse of the electric system in this area, with serious economic results. This whole matter is more fully covered in the industry report of the Electric Power Division.

The Plant and Its Function In Enemy Economy.

1. Product of the plant and its importance in enemy economy.

This report covers a group of primary substations in the Tokyo area which are listed with their size and location below:

Name	Location	Transformer Capacity, Kva
Komatsugawa	1105 Higashi-funabori-cho, Edogawa-ku, Tokyo	108,000
Kameido	20, 2-chome, Hirai-machi, Edogawa-ku, Tokyo	108,000
Hanabata	1,350 Nishi-Kahei-cho, Adachi-ku, Tokyo	168,000
Keihoku	1,088 Nishi-cho, Soka-machi, Kita-adachi-gun Saitama-ken	162,000
Hatogaya	2,780 Mitsuwa, Kawaguchi-shi, Saitama-ken	168,000
Wadabori	Izumi-cho, Suginami-ku, Tokyo	150,000
Total		864,000

These are not all the primary substations in this area, and these particular ones were not selected because of any individual specific significance. Rather, they were chosen as a representative group, in order to determine visually the type of construction, operating conditions, and other factors. A substation is an important link in the chain of distribution of electric current from its source of generation to the ultimate consumer, and its destruction would prevent the use of the current. However, the individual importance of any substation must be determined by considering whether an adjacent substation could function as a substitute in case of destruction. In the case of these substations, as well as all the substations serving the highly industrialized and populated area of Tokyo, Kawasaki, and Yokohama, there were, in all instances, other facilities available so that the destruction of any one station would have caused no serious economic effect. There are many incoming transmission lines from various groups of hydro generating plants; these lines individually feed into several different substations, and the substations in turn are tied together in the form of a loop or ring system around the area. Since transmission lines themselves are unlikely to be destroyed for any distance, the destruction of any substation, or even several substations, could be overcome either by installing a by-pass around the damaged station, or by rerouting generation from the hydro plants via some other transmission line to another station. All substations were greatly over capacity, so that the actual capacity loss of one, or even several, would not be an effective deterrent to the continuous functioning of the system. Only by the destruction of all or a majority of the primary substations, together with a portion of the steam plants in the area, could a definite and effective disruption of the power supply be accomplished. These substations furnished their output to a secondary distribution system; this system interconnected the other substations in the form of a ring about the area. Therefore, the individual importance of these substations could not be determined, except in respect to the relation which their individual size bears to the total demand of the area.

2. Physical description of plant.

All of these stations are outdoor type and occupied areas averaging about 7 acres each. The substation structural work is of fabricated steel, and occasionally reinforced concrete was used in the upright supporting members. Reinforced concrete buildings house the offices, control rooms, repair shops, synchronous condensers, etc., while wooden buildings are used as warehouses, employees' houses, and the like. More complete equipment details, load and other data are given in Exhibit A, and photographs of the various stations are shown in Exhibit B, photos 1–23. When the main dispatching headquarters of the Japan Electric Generation and Transmission Company in down-town Tokyo was destroyed by fire, the headquarters was set up temporarily in the Wadabori Station. The principal function of all these stations is to receive current from the hydro plants in central and north Honshu and transform, switch, control and feed it into the 66-KV network.

3. These substations are owned by the Japan Electric Generation and Transmission Company, and information was furnished by K. Sugawara, chf, and E. Ebinuma, chf engr of the Tokyo district.

Attacks.

There were no primary attacks on these substations, but on 2 occasions there was slight damage during area raids on Tokyo. On 26 May 1945 about 200 IBs fell on the Kameido station and on 13 July 1945, 7 HE bombs fell on the Hatogaya station.

Effects of Bombing.

1. Physical damage.

In the 26 May 1945 raid, one warehouse and one dwelling burned and one transformer bushing was broken at the Kameido station. Although about 200 IBs fell on the station, of which 33 fell directly on the concrete roof of the control house, the entire damage was negligible. On 13 July 1945 the 7 HE bombs that fell on Hatogaya station did no damage. Some slight attempt at providing bomb protection had been made. Cinder-filled wooden barriers had been placed around transformers, and the control buildings had been painted dark gray or camouflaged by irregular color patterns.

2. Production loss.

None.

4. Recuperability cycle.

The damage done was so slight that recuperation was immediate. However, had there been any serious damage, actual recuperation would have been very lengthy, although modification or substitution would have been possible under certain conditions.

4. Vulnerability.

Since no damage was done, no proven conclusions as to specific vulnerability can be stated. However, these stations were located in the plains around Tokyo where they could have been reasonably easily located with the transmission lines as landmarks, especially from lower altitudes. Since one station received about 200 IB hits with no appreciable dam-

age, it is clear that this type of bomb is not effective against substations. However, the equipment in substations is, to a large extent, fragile and open, and, in addition, much of it is highly specialized and not easily replaced, such as high voltage oil or air blast circuit breakers and transformers. Such equipment is also highly susceptible to damage from fragmentation or blast. Therefore, it is considered that substations are very vulnerable to damage from HE bombs.

Intelligence Check.

1. Air Objective Folder 90.17 for Tokyo Area, issued by the Office of Assistant Chief of Air Staff, Intelligence, listed only one of these substations, namely, Hatogaya, and the information given on it was meager and inaccurate. JTG listed none of these substations except Hatogaya, and, in this instance, the information given was meager and inaccurate. OSS did not list any of these substations.

2. No photo interpretation of damage, recuperation, or dispersal was made since none occurred.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

These stations were well constructed and maintenance was good. They all had over-capacity which was not done purposely as a war time protective measure, but was partly a result of much duplication and paralleling of facilities prior to consolidation into one operating company, and partly the consequence of a tendency of the Japanese to install facilities far in excess of immediate needs. This over-capacity did, however, act somewhat as a safeguard in the matter of recuperation from possible bombing losses, since they could have shifted loads to other stations, by means of network or loop lines, or could have rerouted incoming current via other transmission lines. This does not mean that substations would not be effective targets in eliminating power, but rather that the effectiveness would lie only in the destruction of all or a majority of them. This matter is covered fully in the Electric Power Industry Report.

EXHIBIT A—TOKYO TRANSMISSION SUBSTATIONS

Primary Substation Equipment Data

Station	Komatsugawa	Kameido	Hatabata	Keihoku	Hatogaya	Wadabori
MAIN TRANSFORMERS						
Total installed capacity—KVA	108,000	108,000	168,000	162,000	168,000	150,000
Total spare capacity not installed KVA	1 Spare Coil	54,000	------	18,000	------	------
Number of transformers total	6 (1 Phase)	9 (1 Phase)	6 (1 Phase)	10 (1 Phase)	6 (1 Phase)	3-(3 Phase)
Maker of transformers	Westinghouse	GE	5-Westinghouse 1-Mitsubishi	4-GE., 2-Shibaura 3-Fuji	Westinghouse	Mitsubishi
Transformer characteristics:	CAP. KV	CAP. KV	CAP. KV	CAP. KV	CAP. KV	CAP. KV
Primary capacity—KVA and voltage	15,000 84.9	15,000 80.8	25,000 80.8	13,333 85	25,000 80.8	45,000 15.4
Secondary capacity—KVA and voltage	18,000 38.1	18,000 13.5	28,000 38.2	18,000 38.1	28,000 38.2	50,000 66
Tertiary capacity—KVA and voltage	10,000 11	10,000 11.5	16,700 11.6	13,333 10.45	16,700 11.6	15,000 11
CONDENSERS—3-PHASE						
Total installed capacity—KVA leading	25,000	45,000	25,000	60,000	75,000	45,000
Rotary (R) or static (S)	1-R 1-S	3-R	R	1-R 1-S	1-R 1-R 1-S	2-R 1-S
MAKER	GE Sumitomo	Westinghouse	GE	Westinghouse Hitachi	GE Mitsubishi Sumitomo	Westinghouse Sumitomo
Capacity—KVA leading	15,000 10,200	15,000	25,000	30,000 30,000	25,000 30,000 20,000	15,000 15,000
Voltage	11,000 11,000	11,000	11,000	11,000 11,000	11,000 11,000 11,000	11,000 11,000
Speed	750	750	600	600 ------	600 600 ------	750 ------
TRANSMISSION SYSTEM—INCOMING LINES:	Nankatsu-Tokyo loop—2-circuits 140-KV	Joetsu main 2 circuits 140-KV	Joetsu branch 2 circuits 140-KV Senju Tie 2 circuits 66-KV Nairin-Tokyo loop 2 circuits—66-KV	Kurobe main 2 circuits 140-KV Inawashior main 2 circuits 140-KV Nankatsu-Tokyo loop—2 circuits 140-KV	Inawashior new main—2 circuits 140-KV Nankatsu-Tokyo loop—2 circuits 140-KV	Chitose switching station line—2 circuits 140-KV
OUTGOING DISTRIBUTION FEEDERS:	13 Feeders 22 KV 5-3.3-KV local local transformer 6,000 KVA cap 22/3.45-KV	12 Feeders 22 KV 6-3.3-KV local local transformer 6,000 KVA cap 22/3.45-KV	7 Feeders 66 KV	8 Feeders 66-KV	Tie lines 66-KV Nairin Tokyo & Nonaka 4 11-KV	8 Feeders 66 KV 3-Feeders 22-KV local transformer One 7500-KVA, 3-phase 66/22-KV (plus 1 spare bank)
Peak load-KW—October 1945	10,000	14,700	51,000	23,500	108,000	------
October 1944	38,000	62,000	138,000	64,300	119,000	------
Output-KWH—October 1945	3,056,000	6,327,000	13,879,000	7,238,000	26,722,000	------
October 1944	13,210,000	24,898,000	52,194,000	19,623,500	29,947,000	------

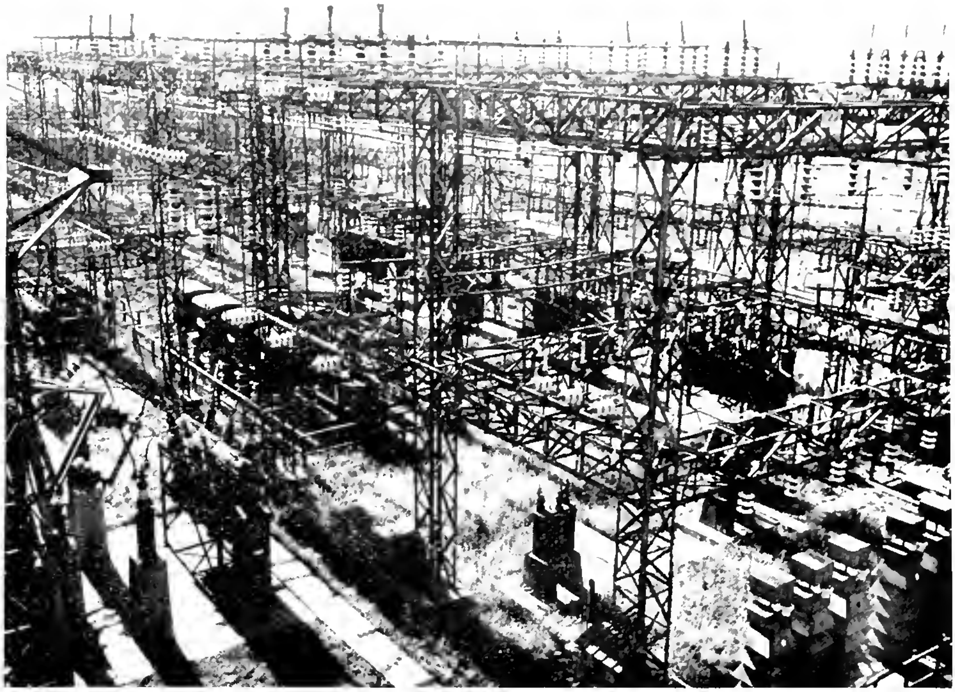

Photo 1—140-KV and 22-KV switchyard. Komatsugawa substation

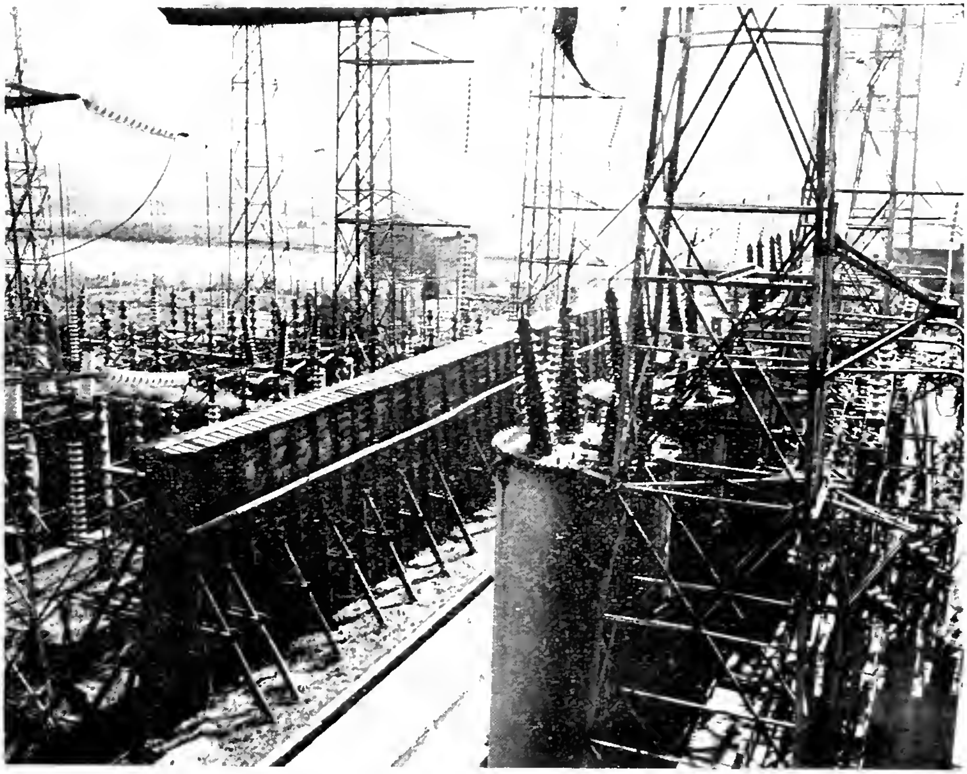

Photo 2—Komatsugawa substation—140-KV transformers. Note cinder-filled wooden protection barriers

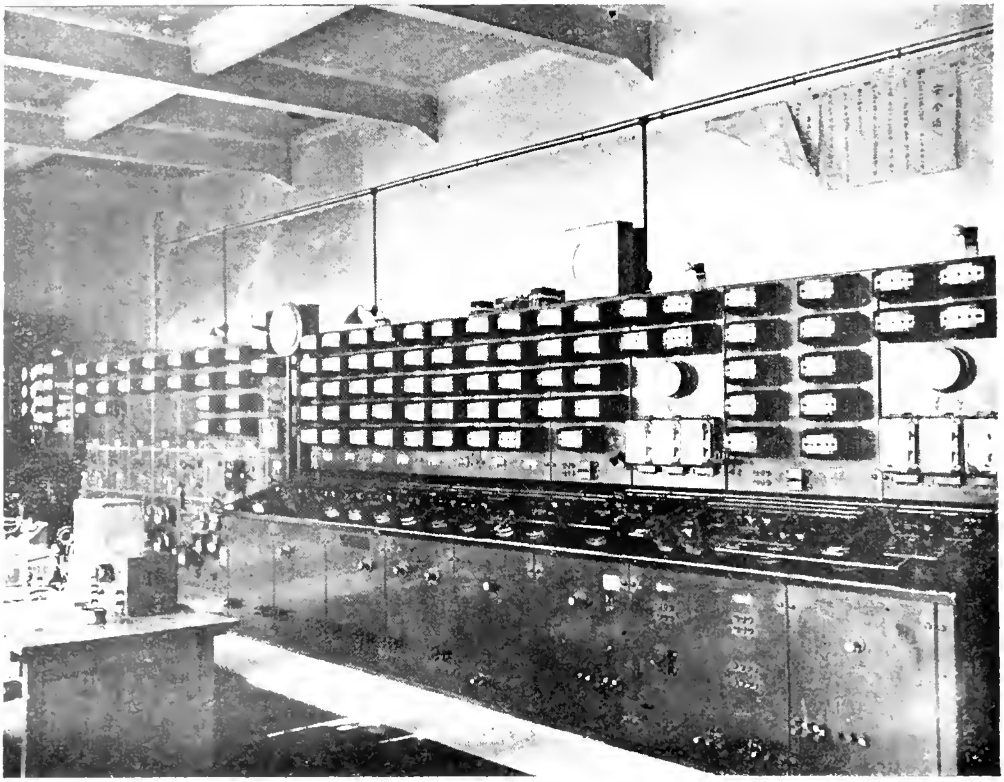

Photo 3—Komatsugawa substation—Control room and board

Photo 4—140-KV and 22-KV switchyard. Control building in background. Komatsugawa substation

Photo 5—Switchyard and 22-KV outgoing lines. Komatsugawa substation

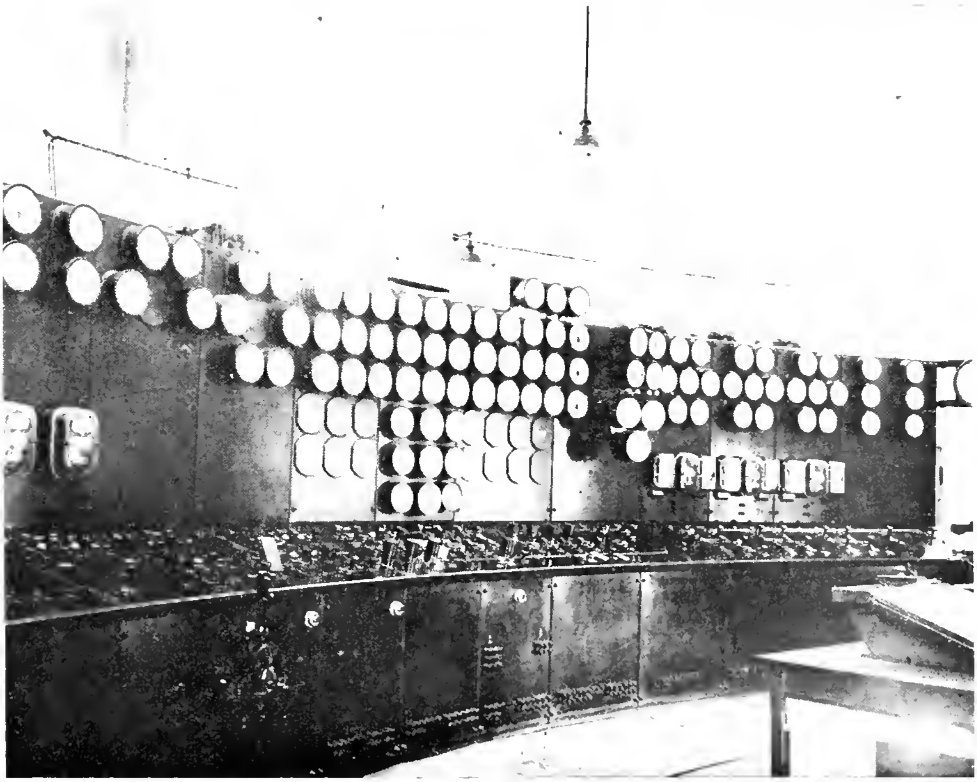

Photo 6—Kameido substation—Control room and board

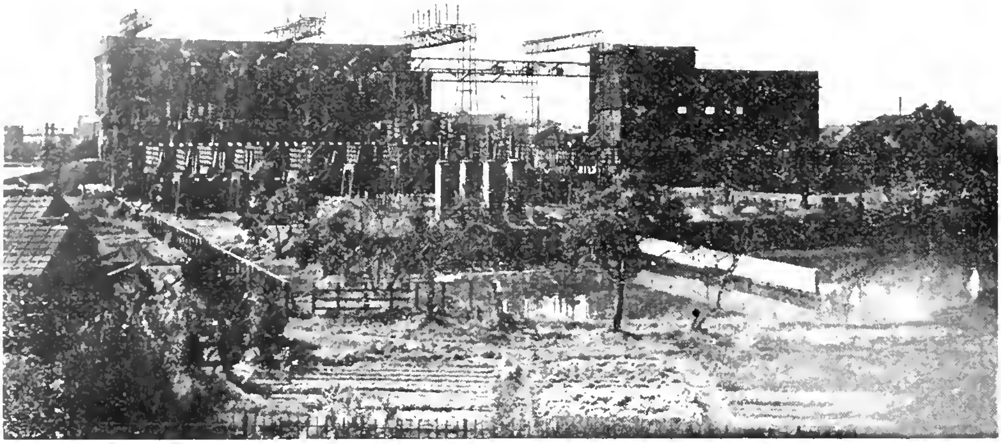

Photo 7—Kameido substation—Switchyard, control building to left, repair and testing building to right

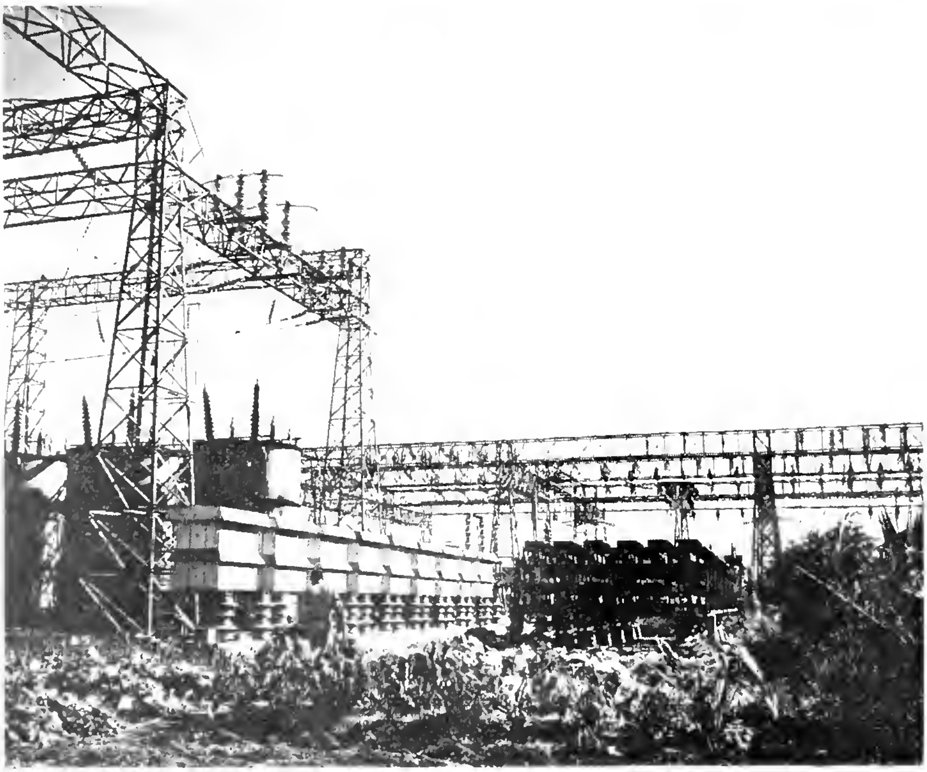

Photo 8—Hanabata substation—Ground resistors on 140-KV neutral

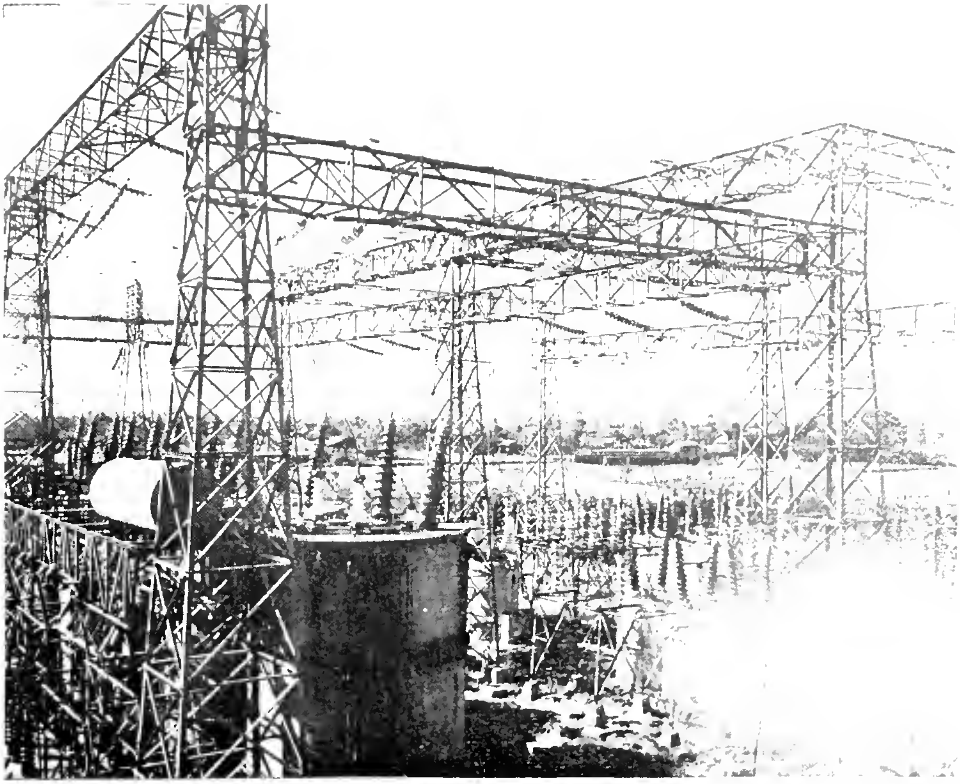

Photo 9—Hanabata substation—140-KV switchyard

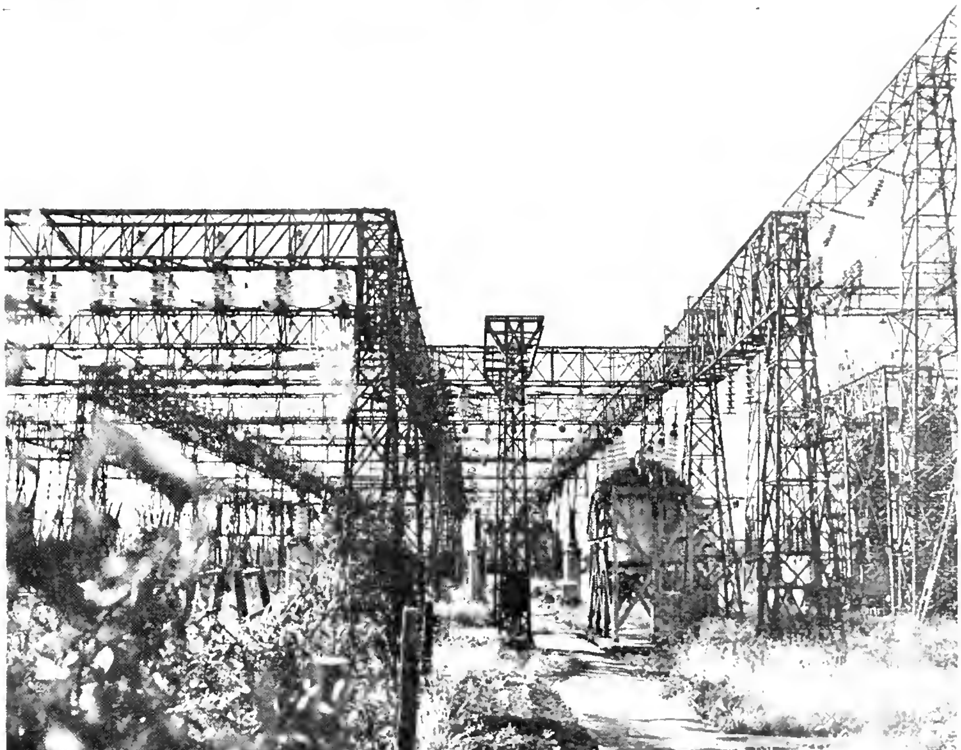

Photo 10—Hanabata substation—66-KV switchyard

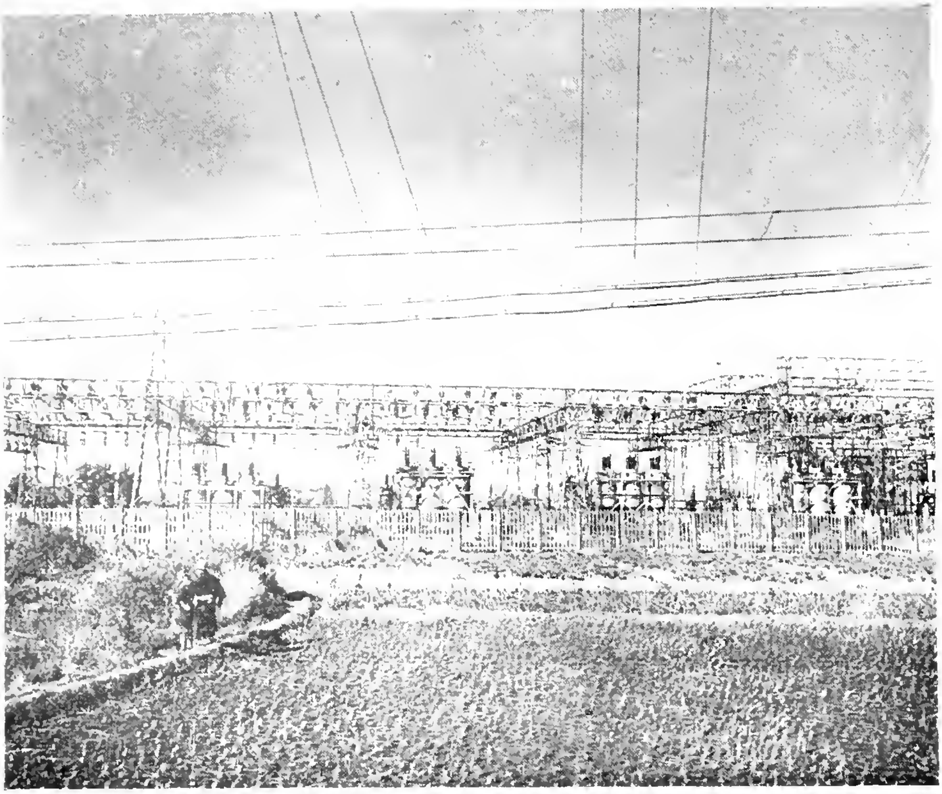

Photo 11— Hanabata substation—66-KV switchyard

Photo 12—Keihoku substation—Area surrounding station

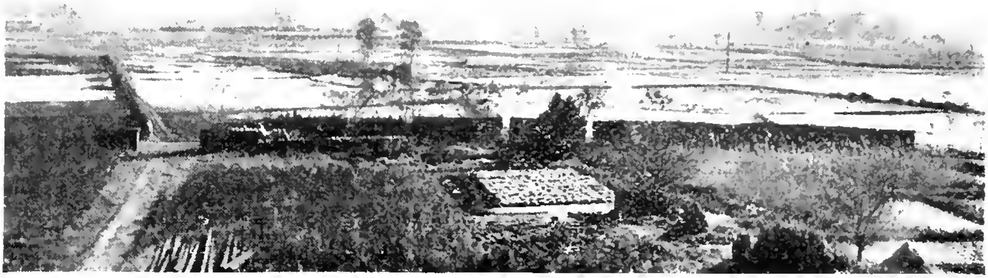

Photo 13—Keihoku substation—Area surrounding station

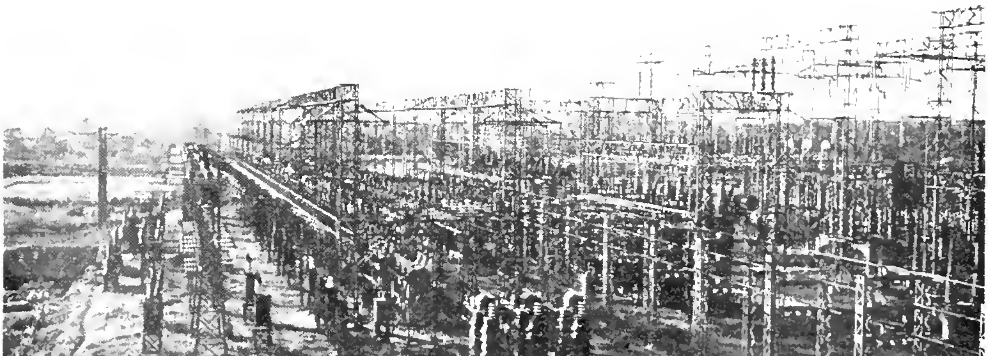

Photo 14—Keihoku substation—Switchyard

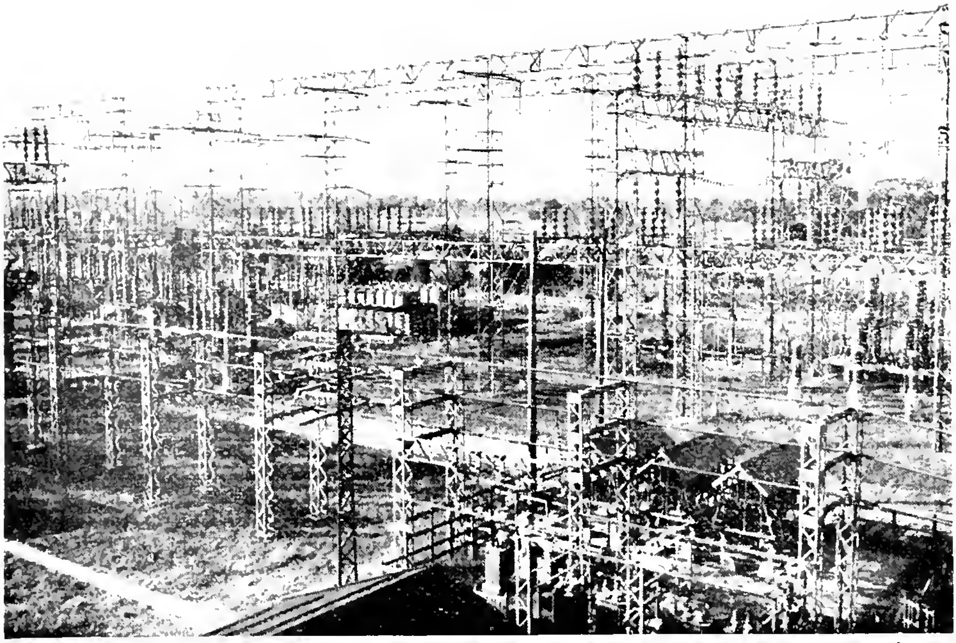

Photo 15—Keihoku substation—Switchyard

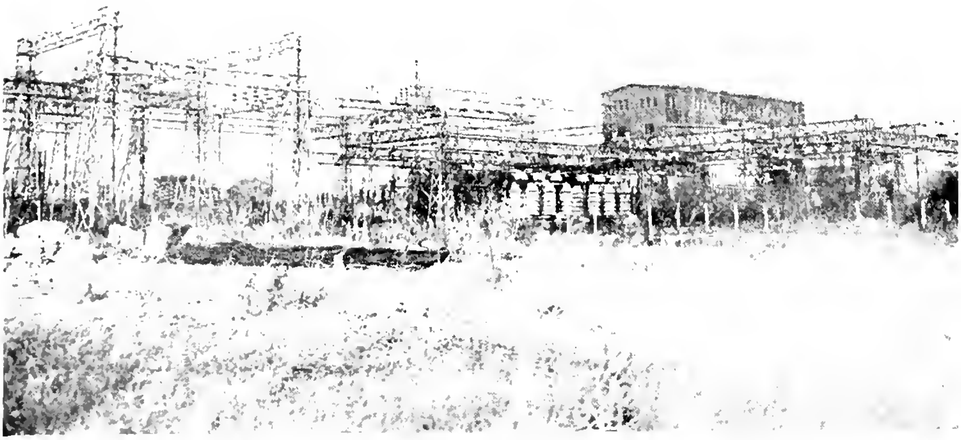

Photo 16—Hatogaya substation—Switchyard with control building in background

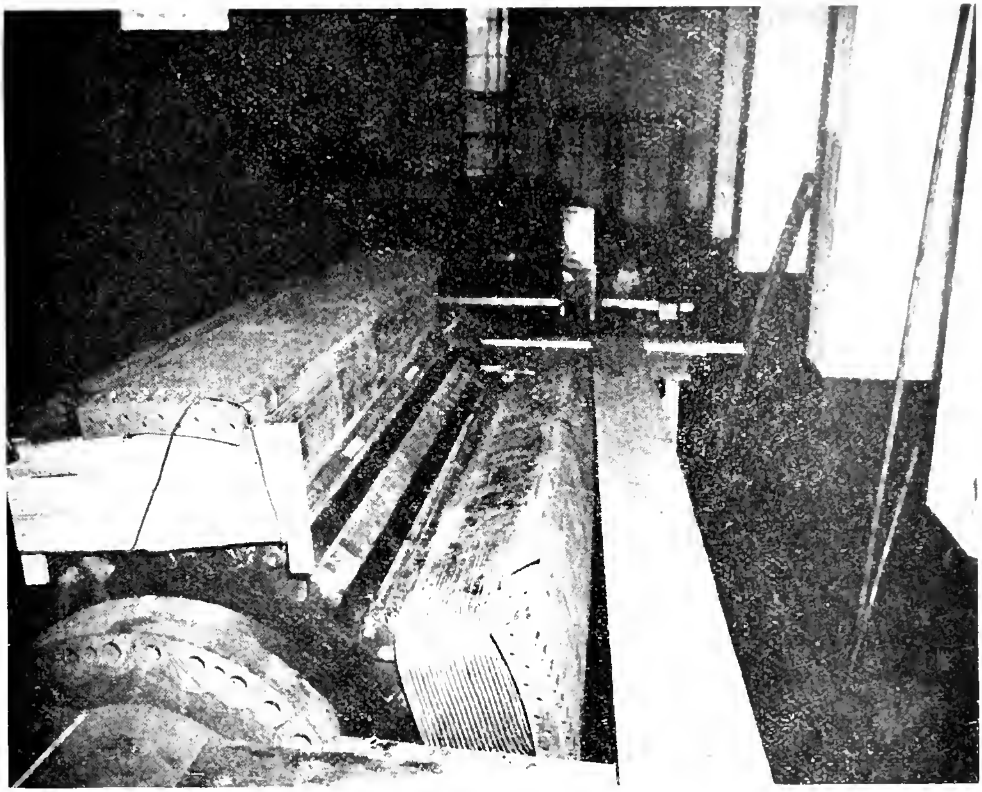

Photo 17—Hatogaya substation—30,000-KVA Mitsubishi condenser out of service because of burned out field coils (not as a result of bomb damage.)

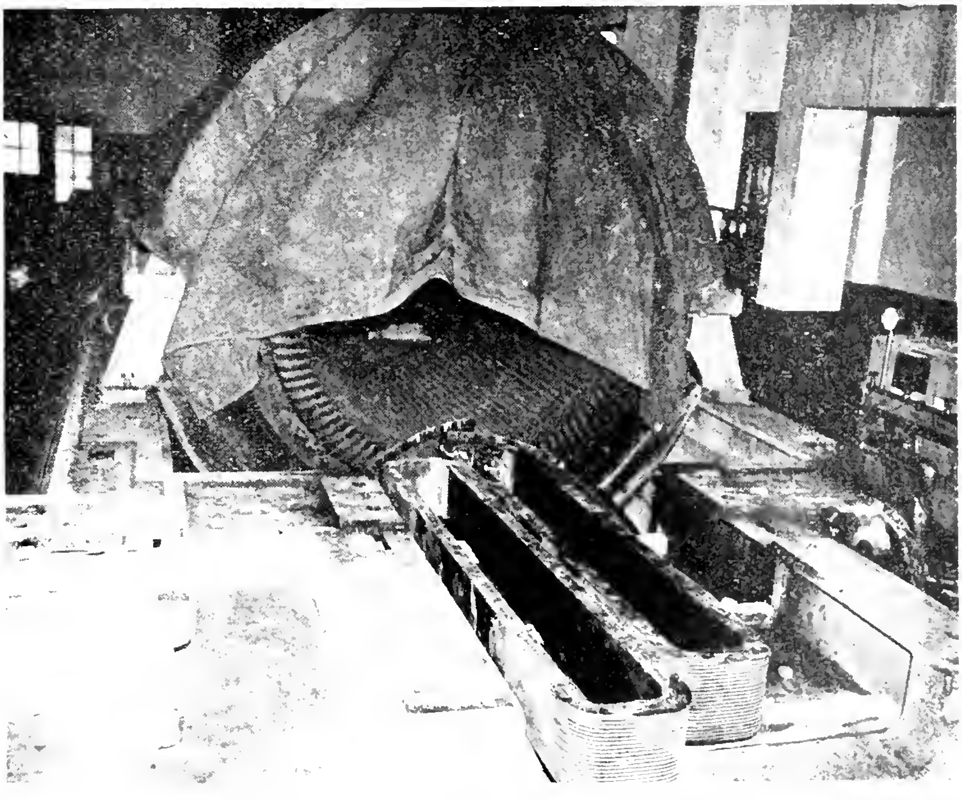

Photo 18—Hatogaya substation—30,000-KVA Mitsubishi condenser out of service because of burned out field coils (not as a result of bomb damage)

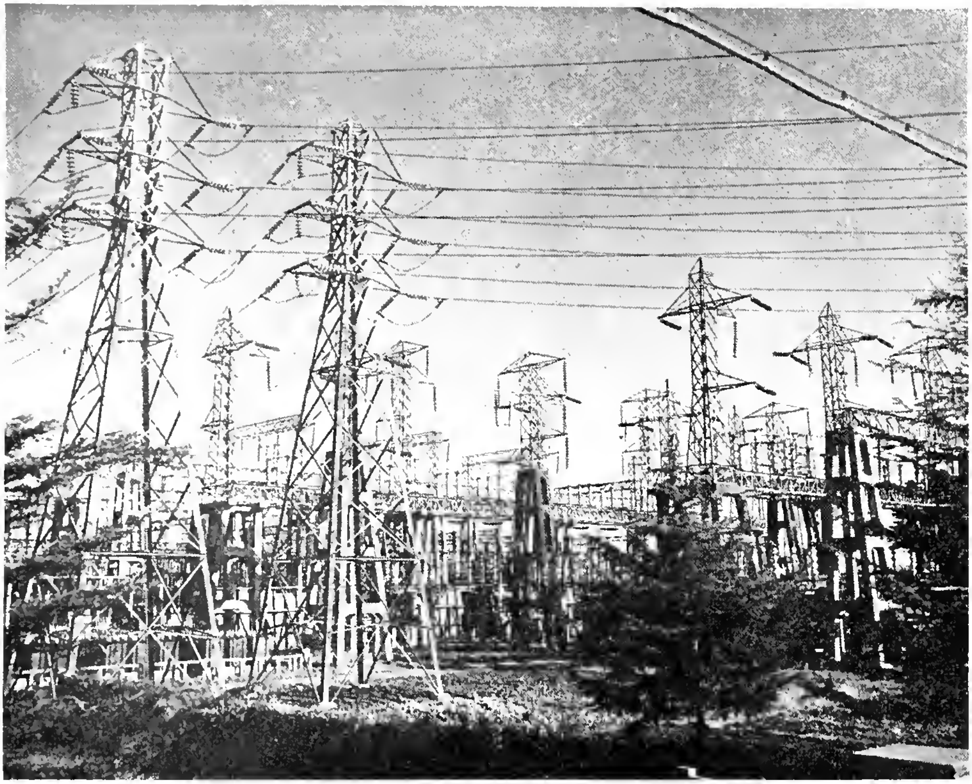

Photo 19—Wadabori substation 110-KV section

Photo 20—Wadabori substation—concrete upright supports

Photo 21—Wadabori substation—Control building

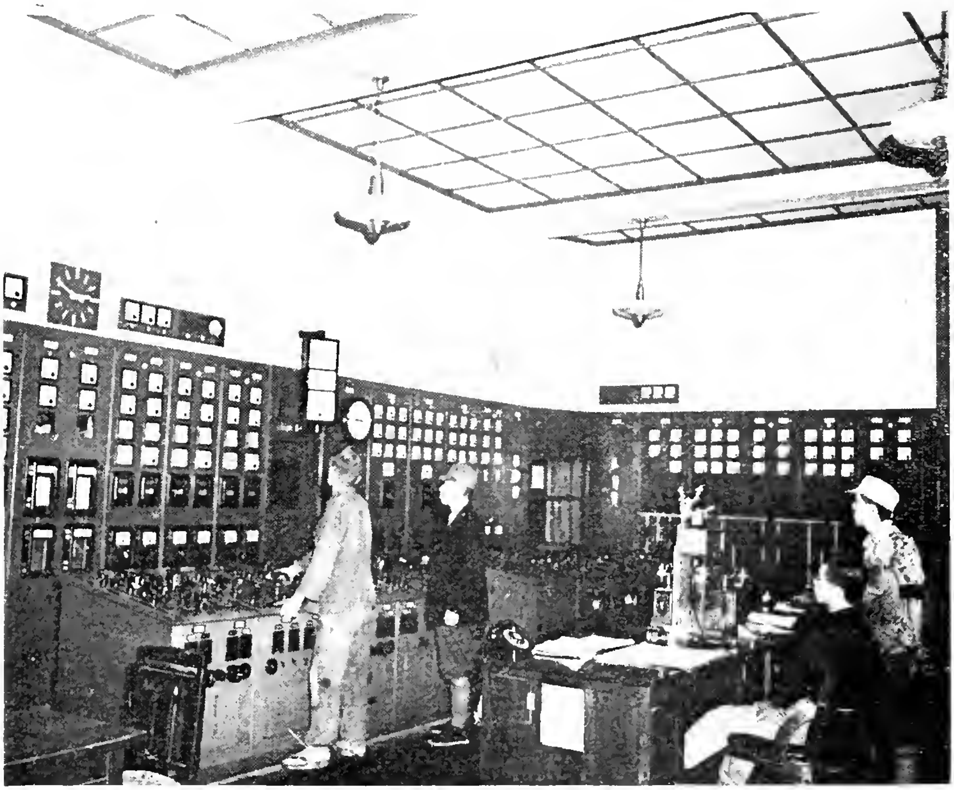

Photo 22—Wadabori substation—Portion of control board

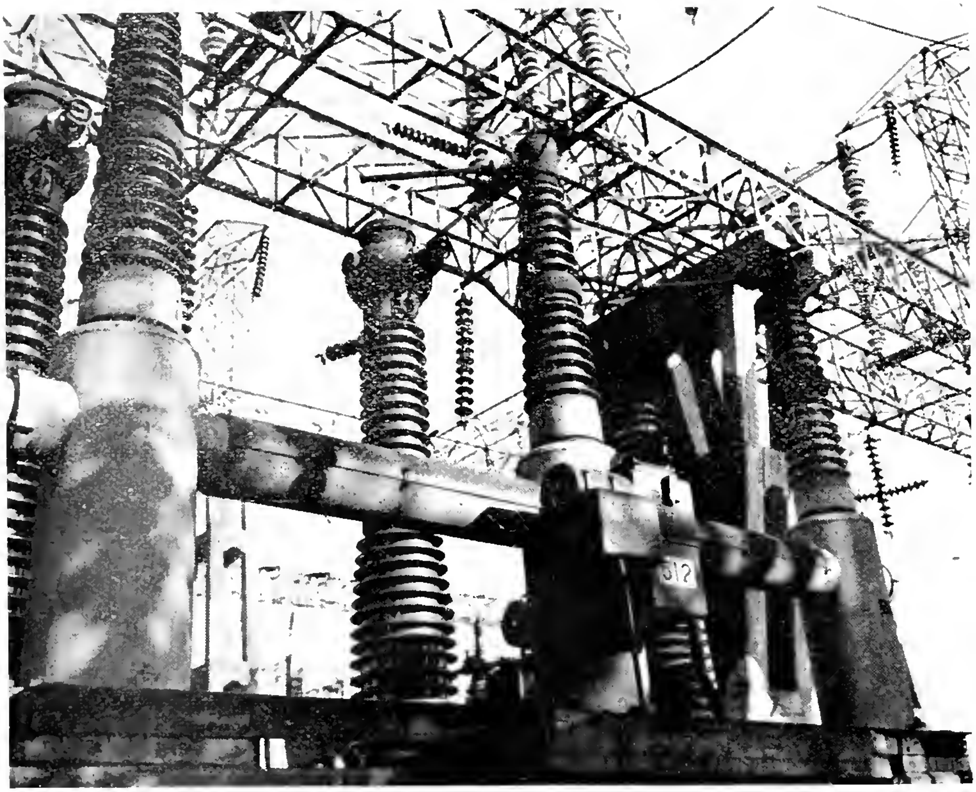

Photo 23—Wadabori substation—140-KV air blast breakers

TOKYO SECONDARY SUBSTATIONS

TOKYO, JAPAN

DATES INSPECTED
26, 27, 28 OCTOBER 1945 AND 1 AND 4 NOVEMBER 1945

Summary.

1. This report covers 9 secondary substations owned by the Kanto Electric Supply Company, which is the electric distributing organization in the Tokyo area. These substations are located in Tokyo or its immediate environs. They do not constitute all the substations there, but are a representative group of various types with different degrees of damage from various causes. The total capacity of these 9 stations is 80,500 KVA in transformer capacity, and their individual sizes are relatively small. These substations do not have any particular significance or specific importance in the enemy economy, except that any substation is an indispensable link in the supply of electric energy from the source of generation to the ultimate consumer. Tokyo was the most important industrial and most populated area in Japan, and, therefore, these substations were equally important in proportion to their size.

2. These substations were never a primary target but were damaged simultaneously with the areas in which they were located, during raids on those areas.

3. Principal damage was done to transformers, switchgear, control boards, and buildings. Most of the damage was caused by fire, but this was largely because of their location in crowded areas adjacent to highly inflammable buildings, and was not the direct effect of IBs on the stations. Since the area they served was destroyed along with the station, the production loss was of no economic importance. It is shown that recuperation is a long process and that substations are highly vulnerable. However, where the station is of modern, fireproof construction and isolated from exposure to adjacent highly inflammable buildings, IBs have little or no direct or indirect harmful effects. Strafing produced, in one instance, great damage, but since strafing is possible only when air defense will permit low altitude attack, it is not considered to be a proper method of general effectiveness. HE bombs are the proper weapon to produce the greatest and most lasting damage to substations.

4. These substations had not been listed in any intelligence data and, with one minor exception, no specific damage assessments had been made. Secondary substations are too numerous to list individually unless one happens to serve some specific industry of great military importance.

5. There is a great tendency on the part of the Japanese to install over-capacity in their substations, and the peak loads ever carried were, in most instances, far below the station capacity. This was not done purposely as a war safety factor, but might well have proven beneficial; for in the event of destruction of a single station, adjacent stations could have been utilized for substitution. However, since, in the case of these stations, the area was destroyed along with the station, the load was simultaneously lost and any need for alternate facilities was neutralized. Of particular significance is the fact that where good, modern, fireproof construction was used and proper protection provided against inflammable surroundings, as in the Oshima substation, incendiary bombs had no effect even though direct hits were made on the station.

The Plant and Its Function In Enemy Economy.

1. Product of the plant and its importance in enemy economy.

This report covers a group of damaged secondary or distribution substations in the city of Tokyo or its immediate vicinity. The names of these substations with their capacities are as follows:

	KVA
Chigasaki	11,500
Hachioji	16,500
Hongincho	3,000
Jukkengawa	9,000
Kojimachi	6,000
Nippori	9,000
Oshima	12,000
Ozaku	7,500
Sugamo	6,000
Total	80,500

These stations are only a few of all the distribution substations in Tokyo and its vicinity, and there is no particular significance in their selection, other than that they are representative of the various types, use

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several different kinds of construction, and present a variety of degrees of damage. Substations are an important link in the supply of electric energy from its source of generation to the ultimate consumer, and, therefore, their destruction prevents the use of the energy. The importance of a substation in an enemy economy is measured in relation to its size and the type of consumer. Some substations serve only residential or small commercial loads, while others may supply important industrials. However, as a safety factor, it is usual to interconnect adjacent substations so that, in the event of the loss of one, interruption of service is avoided by use of substitute or alternate facilities. Furthermore, distribution substations are generally not large individually, and they are relatively unimportant, but collectively, or in groups, they do assume a definite and important part in the continuous supply of energy, which is a prime factor in an enemy economy.

2. Physical description of the plant.

For purposes of convenience, each station is separately listed with its location, principal features, function, attacks, damage, production loss, recuperability, vulnerability, and significant evaluation and impressions.

Chigasaki Substation.

Location—Kanagawa, Koza, Chigasaki.

Size—There is a total capacity of 11,500 KVA made up of 1 bank of three 2,000-KVA, 66/3.3-KV, 1 bank of three 1,500-KVA, 66/22-KVA with one 1,500 spare, and 1 bank of three 333-KVA, 66/22-KVA with one 333-KVA spare. There are 2 incoming 66-KV circuits and 1 outgoing 22-KV and six 3.3-KV circuits.

Principal features—This substation is an outdoor type with steel, box, girder construction. The transformers are installed in a straight line on one side of the structure. The control is from a small adjacent building. There is an additional steel structure near the main structure for a 22/3.3-KV switching arrangement.

Function—It supplied current to residential and rural customers at a very low load factor. There were no industrial installations in this area. The normal load on this station was about 7,000 to 8,000 KW, and the annual output was about 4 million KWH.

Attacks—The only attack was on 6 August 1944. Four P-51 planes approached from the north at 0930 and strafed the station at a low altitude, with 50-cal armor piercing, and incendiary ammunition. The planes circled the station 3 times. About 300 Japanese soldiers came to put out the fire.

Principal physical damage—The end transformer was struck by an incendiary bullet which caused this transformer to explode; the fire spread and involved the other transformers of the bank. The middle transformer of the second bank also was fired by an incendiary. The fire spread throughout the station, completely destroying all 10 transformers. Three 66-KV oil circuit breakers were completely destroyed and one was about 25 percent destroyed. The heat destroyed about 30 percent of the steel structure. Two 22-KV oil circuit breakers were about 25 percent destroyed by heat. Numerous bus supports, bushings, and insulation were damaged by bullets. Wherever a bullet struck a transformer, damage was complete because of fire. Exhibit A, photos 1-8, show some of the damage.

Production loss—When this station was put out of commission, the load was transferred to the Hiratsuka substation. This method of load supply is being used at present, and no attempt has been made to rebuild the station. A temporary bank of three 1,000-KVA, 22/3.3-KV is being used to feed the 3.3-KV feeders. The former 22-KV outgoing line is being used as an incoming line from Hiratsuka.

Recuperability—A large part of the steel work of the station will need to be replaced and new transformers and oil switches will be needed. A 75 percent rebuild job will be necessary on the electrical bus work and control wiring. If equipment is made available, from 9 to 12 months will be required to rebuild the station.

Vulnerability—This station was especially vulnerable from the air because it was located in a wide, open area, surrounded by small residential structures. The supply lines are on steel towers and come across open country; this made it very easy to find the station by following the lines.

Significant evaluation and impressions—The destruction of this station was of psychological value rather than real value. A station of this size can usually be taken from the system without causing an excessively long interruption to service. The service interruption is more of an inconvenience than anything else. The people of a community look upon the power supply as a major item and it is of great importance in their eyes. When it is interrupted, it has a marked effect on their minds, and brings the war to their door.

Hachioji Substation.

Location—Tokyo, Hachioji, Hiraoka-machi.

Size—There is a total of 16,500 KVA, made up of one 7,500-KVA, 66/3.3-KV, three-phase transformer

and one bank of three 3,000-KVA, 66/3.3-KV, single-phase transformers with one 3,000-KVA spare. The station is supplied by two 66-KV lines and has eleven 3.3-KV outgoing circuits.

Principal features—This station is a combination outdoor-indoor type; the transformers are located in the outdoor steel structure, and the low voltage equipment is located in a building. The building is a one-story, concrete structure with a flat roof. The electrical control and switching equipment was of conventional design.

Function—This station is the distribution point for the city of Hachioji, a suburb of Tokyo, and the surrounding rural area. A large cement mill was the largest user of power, but there were also some small industrial plants in the town that made small components for aircraft, and also some textile manufacturers.

Attacks—On 2 August 1945 an incendiary area raid was made in the early afternoon.

Principal physical damage—The substation proper did not receive any direct hits, although 6 IBs dropped near the structure. The fire from the adjacent area spread to the substation building and destroyed part of the building and 6 of the distribution switching bays. The distribution feeders left the station underground. All the cable entrances were destroyed completely. None of the outdoor structure was harmed.

Production loss—The load on the station prior to the raid was about 3,000 KW. The destruction of the area practically eliminated the need for this station. The present load of the area is 200 to 300 KW.

Recuperability—A temporary building has been built and 5 of the 11 distribution circuits have been put back into service, using overhead instead of underground take-off. If equipment and materials were available, the station could be rebuilt to its original capacity in about 3 months.

Vulnerability—This station is vulnerable to direct or near hits by HE bombs. The station would be rendered inoperative for a long period, if the large tranformers were destroyed.

Significant evaluation and impressions—The loss was caused by fire from adjacent inflammable structures (Exhibit A, photos 9 and 10) and not by direct action of the incendiaries on the station. Had the station been in a cleared area, no damage would have resulted. This shows that only in rare and unusual instances do incendiary bombs damage substations.

Hongincho Substation.

Location—Tokyo, Nihombashi-Ku, Hongoku-cho.

Size—There is a total capacity of 3,000 KVA, made up of one bank of three 1,000-KVA, 22/3.3-KV transformers with one 1,000-KVA spare. Originally, it had a capacity of 9,000 KVA made up of one bank of three 3,000-KVA transformers with one 3,000-KVA spare. The station is supplied by three 22-KV underground lines and feeds eight 3.3-KV feeders.

Principal features—This station was built in 1910. It is a complete indoor type, housed in a two-story building of concrete construction, with a peak roof. The electrical equipment is installed on pipe frame work. The station location is in a residential area. To protect against fires during earthquakes, steel shutters were installed over the windows. (Exhibit A, photo 11).

Function—This station is a distribution station feeding a residential and small commercial area. The load on the station was 3,000 KW before the raid and was reduced to less than 1,000 KW after the raid. The load is back now to 2,000 KW, feeding into an undamaged area.

Attacks—The only attack was on 29 November 1944, which was the date of one of the first incendiary raids on the Tokyo area.

Principal physical damage—Two incendiaries struck the roof directly, making 2 small holes, neither of which was large enough to allow the bombs to come through. The entire area was destroyed by fire but no damage was done to the station. The steel shutters over the windows protected the electrical equipment.

Production loss—The destruction of the area almost entirely eliminated the need for this station.

Recuperability—No damage.

Vulnerability—This station is well constructed and not vulnerable to incendiary bombs unless roof penetration can be accomplished. It is vulnerable to HE on direct hits. It is well protected against fire from surrounding areas.

Evaluations and impressions—It was interesting to learn that this station is one that operates on a two-shift basis of 12 hours in each shift, with 2 men on a shift. The men rotate the shifts and live in the station. Each man has 2 days off per month. An impressive fact is that incendiary bombs fell directly on the station with no effects. This shows that this type of bomb is not effective against stations in which there is no inflammable construction.

Jukkengawa Substation.

Location—Tokyo, Kameido-machi.

Size—There is a total capacity of 9,000 KVA, made up of one bank of three 3,000-KVA, 22/3.3-KV with one spare 3,000-KVA transformer. In addition, there is one bank of three 500-KVA, 3.3-KV, 200-V, with one 500-KVA transformer for a spare, to supply a

special power circuit. The station has four 22-KV underground incoming lines, and six 3.3-KV outgoing lines.

Principal features—The station is an indoor type, located in a three-story concrete building with a peak roof. The transformers are on the first floor, the oil switches and disconnects on the second floor, and switchboard on the third floor. The station is quite old, and the electrical equipment and installation are of conventional type. It is located along the canal with industrial buildings on 3 sides. To the rear of the building is one of the principal warehouses of the Kanto Electric Supply Company, where they stored wire, cable, insulators, and small transformers and maintenance equipment.

Function—The station furnished electric supply to an industrial area made up of fairly large industrial concerns manufacturing machine parts and chains.

Attacks—The only attack was on 10 March 1945 during an incendiary raid on the general industrial area.

Principal physical damage—The warehouse was a light building and burned readily and the substation was exposed to this fire without any protection. The fire spread to the station and completely destroyed the building and all the electrical equipment. In front of the station there were stored four 3,000-KVA, 22/3.3-KV transformers, which were also destroyed.

Production loss—This station supplied only the immediate industrial area which was completely destroyed at the same time, and so the need for this station was eliminated.

Recuperability—A complete rebuilding will be necessary, and if equipment and materials are available a new station can be built in from nine months to a year.

Vulnerability—This station was destroyed only because it was located in a congested industrial section and surrounded on 2 sides by closely-built, small industrial buildings. Otherwise, it would not have been affected by incendiary bombs.

Significant evaluations and impressions—Although the station was of fireproof construction, the proximity of highly inflammable buildings was the cause of its complete destruction. Installations as important as this should be isolated.

Kojimachi Substation.

Location—Tokyo, Kojimachi-cho.

Size—There is a total capacity of 6,000 KVA, made up of one bank of three 2,000-KVA, OISC, 22/3.3-KV transformers with one 2,000-KVA spare. The station is served by two 22-KVA underground circuits and supplies twelve 3.3-KV distribution circuits.

Principal features—This substation is an indoor type, housed in a reinforced concrete building of 3 stories, with a flat roof of concrete. The electrical construction is conventional indoor type, similar to U.S. construction of the early 1920s.

Function—This station provided the electric supply to residential areas, some small commercial establishments, and the Imperial Palace. Normally, the station carried a maximum load of 3,000 KW. The annual output was about 6 million KWH.

Attacks—There was one attack on 25 May 1945 with no direct hits on this station. Some 50-cal expended incendiary cartridges were picked up in the adjacent area.

Principal physical damage—The fire from the adjacent area broke the glass in a steel door, allowing flames to ignite the oil in a 3-phase voltage regulator. This fire destroyed the first floor bus work and did considerable damage to the building. On the second floor the windows were barricaded on the inside with wood as a protection against explosion. These barriers caught fire and started a fire in the bus structure which destroyed the 22-KV cable risers, several oil circuit breakers, and the entire switchboard. The transformers were completely destroyed. (Exhibit A, photos 14–20).

Production loss—The output of this station was reduced to zero. Only about 200 KW of the load remains in this area, and that is being supplied from other stations.

Recuperability—If equipment can be obtained it would take from 8 to 9 months to construct a station to take the place of the destroyed one.

Vulnerability—This station was destroyed by IBs only because it was located in an area closely surrounded by inflammable buildings. It was, however, vulnerable to HE bombs. The electrical equipment was installed in a congested manner and heavy damage would invariably follow HE bombing.

Significant evaluation and impressions—The destruction of the service area of this station eliminated the need for the station. A new station can be constructed in time to supply service to the new reconstructed area.

Nippori Substation.

Location—Tokyo, Arakawa, Nippori-cho.

Size—There is a total capacity of 9,000 KVA, made up of one bank of three 3,000-KVA, 22/3.3-KV transformers with one 3,000-KVA spare. The station is supplied by two 22-KV underground lines and sup-

plies nine 3.3-KV distribution circuits. The 3.3 feeders leave the station underground for a short distance.

Principal features—The station is an indoor type station. The building was of reinforced concrete and steel, with a transite peaked roof. The electrical installation was conventional pipe frame work, with the oil switches located on a balcony and the transformers on the first floor. The switch board was also located on the balcony in a separate room.

Function—Electric supply to a large residential area and some small industrial plants, including one industrial machine shop, manufacturing link chain belts. The station load was 3,500 KW maximum and 2,000 KW average.

Attacks—There was one attack on 16 April 1945 when the area was struck by an incendiary raid.

Principal physical damage—One of the incendiary bombs penetrated the transite roof and landed on the transformer floor near one of the transformers. The ensuing fire completely destroyed the transformers, all other electrical equipment, and the building. (Exhibit A, photos 21 and 22).

Production loss—The elimination of the supply area of this station rendered the station useless. At present there is no load in the area except a little lighting that is supplied from another station.

Recuperability—No attempt has been made as yet to rebuild the station because there is no present need for the capacity. About 9 months to a year will be required to build a new station, if materials and equipment can be made available.

Vulnerability—This station was vulnerable to incendiary damage in that the roofing material was not sufficiently resistive. Had it been concrete, there would probably have been no damage. However, HE bombs would have done great damage in either case.

Intelligence check—Intelligence photos show complete destruction of the area. This station is indicated as having suffered exterior roof damage. The real damage is the destruction of the interior equipment, which is difficult to evaluate in aerial photography.

Significant evaluations and impressions—This type of substation was a practical type of design for this service; however, the buildings should be of good concrete construction with a heavy roof.

Oshima Substation.

Location—Tokyo, Joto, Oshima-cho.

Size—This station has an installed capacity of 12,000 KVA, made up of 2 banks, each consisting of three 2,000-KVA, 22/3.3-KV transformers with one 2,000-KVA spare. There are eight 22-KV underground incoming lines and sixteen 3.3-KV outgoing circuits.

Principal features—This is a new substation, completed in 1937. It is a 3-story reinforced concrete building with a flat concrete roof. (Exhibit A, photo 23) The electrical apparatus is installed in individual bays with the bus work mounted on the concrete ceilings. The building is on a plot of ground surrounded on 3 sides by second class residences. The front lot belongs to the company and is open to the street. Because of fires encountered during earthquakes, the building was designed with no windows on any of the side walls but with large windows on the front. This proved to be very effective in saving the station. This station also controls the Sunamachi substation (Exhibit A, photo 25) by supervisory control over the company's own underground telephone cable.

Function—Main distribution substation for an industrial area and some small residences. The load was 8,000 KVA before the raid. Just after the raid the load dropped to 300 KW, primarily pumping load in the station to keep out water. The load has now built up to 1,500 KW.

Attacks—On the morning of 10 March 1945 there was an incendiary raid on the surrounding area.

Principal physical damage—Six IBs landed on the roof but, because of the concrete construction, there was no penetration. The bombs were left to burn themselves out. In one case the bomb landed upright, and there is a perfect hexagon hole just through the surface of the concrete roof about one-quarter of an inch deep (Exhibit A, photo 24). There was no damage to the substation electrical equipment. The adjacent area was destroyed by fire, but since there were no windows on the sides of the building adjacent to the fire, it did not spread to the station.

Production loss—The area supplied by this station was completely destroyed, eliminating the need for the station output.

Recuperability—Not damaged.

Vulnerability—This station is well constructed to protect it against damage by earthquake; this makes it difficult to damage except by direct hit by HE bombs.

Significant evaluations and impressions—This substation is an excellent example of the protective quality of proper construction. Most modern secondary substations are similarly built and therefore present barriers to damage by weapons other than HE bombs.

Ozaku Substation.

Location—Nishitama, Nishitama-mura.

Size—This station has a total capacity of 7,500 KVA, made up of one bank of three 1,000-KVA, 66/3.3-KV and one bank of three 1,500-KVA, 66/22-KV transformers. There are two 66-KV incoming lines, and one 22-KV and six 3.3-KV outgoing lines.

Principal features—The station is an outdoor steel structure, with the transformers in a line on one side of the station. A wooden story-and-a-half control house is adjacent to the outdoor structure. (Exhibit A, photos 26, 27 and 28)

Function—This station supplied electric energy to adjacent residences and rural area. The normal load was 3,000 KW, which now has dropped to about 1,000 KW. No annual output figures were available.

Attacks—On 20 May 1945, at 1030, three planes approached from the NE and strafed the station at very low altitude, using 50-cal armor piercing bullets. This was the only raid experienced at this station.

Principal physical damage—Every transformer in the station was hit with from 2 to 6 bullets. Some penetrated the cooling fins on the radiators and others cut through the fins on the main tanks. About 100 bullets came through the building of which 10 hit the marble switch board and damaged the board and some instruments. (Exhibit A, photo 29) An electric arc started a fire in one transformer; this fire spread to 1 other transformer and 1 66-KV oil circuit breaker which was destroyed. The fire was under control before any of the other transformers or equipment was damaged.

Production loss—This station was not an important link in the system. It was a distribution point for residential and rural load. The loss of production had no direct effect on production capability.

Recuperability—The company promptly moved spare transformers in the bank in place of the ones damaged by fire. While this moving was going on, a very ingenious job of electric welding was done on the punctured transformers. (Exhibit A, photo 30) All the holes were closed and the oil replaced. The station was out of service three days.

Vulnerability—This station could be reasonably easily located because it was in open territory with steel tower transmission lines coming into the station.

Evaluations and impressions—Although, seemingly much damage was done by strafing, recuperation was quick, and the effects were of no consequence. It is not considered that strafing is a proper method of attack against substations, and should only be employed after defense conditions permit low level flying, at which time bombing by HE would be very much more effective.

Sugamo Substation.

Location—Tokyo, Toshima, Sugamo.

Size—The total capacity of this substation was 6,000 KVA, made up of two banks of three 1,000-KVA, OISC, 22/3.3-KV transformers with one 1,000-KVA, OISC spare. There was also a 500-KW, 600-volt, rotary converter for interurban railway service. The station was supplied over two 22-KV circuits and had six 3.3-KV outgoing circuits.

Principal features—This station was a combination railway and light and power station. The building was of brick construction with a peak roof, and had indoor pipe frame work similar to that used in U.S. about 1920.

Function—This station furnished electric supply to several small manufacturing plants, residences, commercial establishments, and electric interurban railway. The maximum load on the station was 4,000 KW with an annual output of about 8,000,000 KWH.

Attacks—This station was not a primary target, but, on 14 April 1945, during an area raid, there was a direct HE hit on one corner of the building, demolishing the side of the building and a corner of the roof. (Exhibit A, photo 33) Subsequent IBs hit the adjacent territory.

Principal physical damage—The HE did considerable damage to the building, but practically none to the electrical equipment. The IBs dropped on the adjacent area started fires that spread to the substation. The fire completely destroyed all the electrical equipment and the station is beyond repair. (Exhibit A, photos 31, 32 and 33)

Production loss—The output of this station was reduced to zero. The destruction of the service area eliminated all but 1,000 to 1,200 KW of the load, which was transferred to other stations. If equipment could be obtained, it would take about 8 to 9 months to rebuild the station.

Vulnerability—This station was vulnerable to IBs only in that the surrounding area was made up of middle class Japanese residences constructed of wood. It is not vulnerable to direct incendiary hits, but is vulnerable to HE bombs, especially if a delayed fuse is used, so that penetration can be made and the bomb reach the lower levels before detonation occurs.

Significant evaluations and impressions—This, is a peculiar case of damage caused by an HE bomb which did not itself cause serious damage, but did cause exposure of the interior of the building. Thereby, the fire from the adjacent area was able to spread

to the station, and caused almost complete destruction. Either the HE or the incendiary by itself would not have had any effective results.

3. All stations are owned by the Kanto Electric Supply Company, which is the distributing organization in the Tokyo area.

4. These stations use from 4 to 10 men per station; they operate in 2 shifts. Any unusual maintenance or repairs are done by separate crews.

Attacks.

This is shown under each individual station.

Effects of Bombing.

The physical damage that occurred is shown under each individual station. In every case, the destruction of the area neutralized the need for the station and, therefore, production loss cannot be measured. Recuperability is proven to be difficult and lengthy where the damage was substantial. Substations, as found from a study of the entire group, are very vulnerable; however, where construction is modern, they are vulnerable only to HE bombs.

Intelligence Check.

Secondary substations were not listed in any of the sources of intelligence information, nor, except in the one instance of the Nippori station, was any mention made of any damage assessment.

Data Relevant To Other Studies.

None.

Evaluations and Impressions.

It was significant that in practically every case damage was complete or very great. Where damage was light, the factors of prevention were good, fireproof construction and elimination of exposure to adjacent inflammable areas. Although fire from IBs caused most of the damage, this was not because of IBs on the stations themselves, but because of exposure to the terrific fire caused by these bombs in surrounding densely built areas. The most effective and dependable weapon against modern substations of either indoor or outdoor construction is HE bombs

Photo 1—Chigasaki substation—front view of building showing 50-cal penetration. The building on front left is temporary new building. Bomb shelter in left foreground

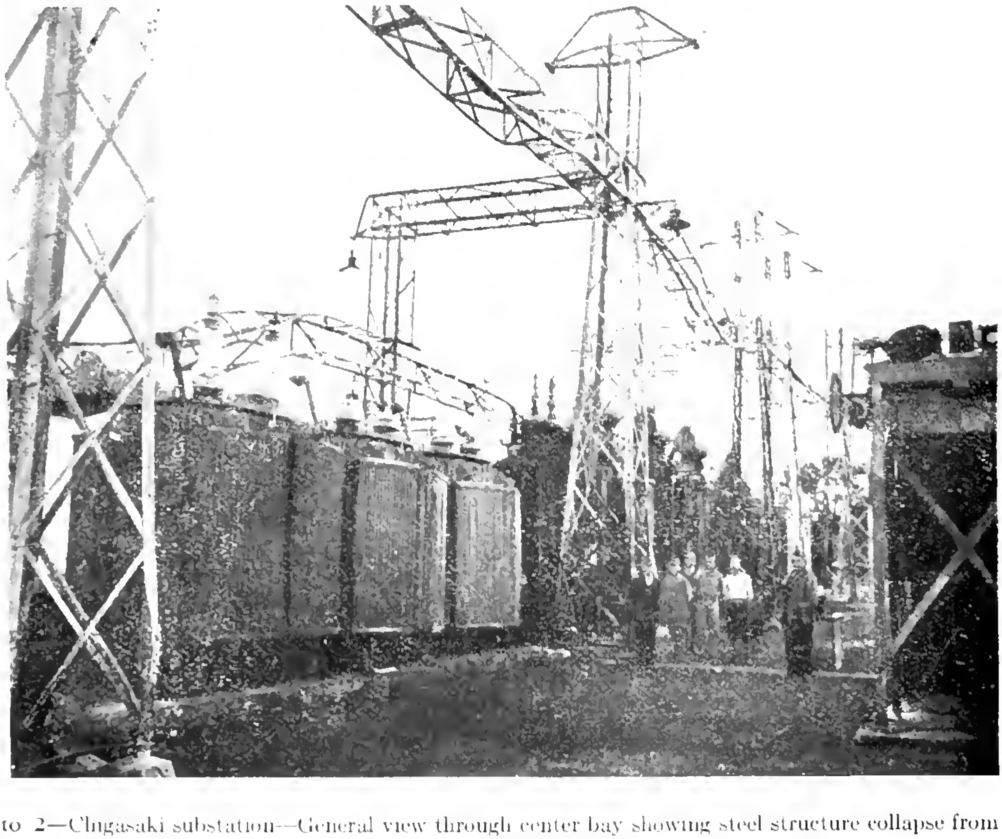

Photo 2—Chigasaki substation—General view through center bay showing steel structure collapse from heat

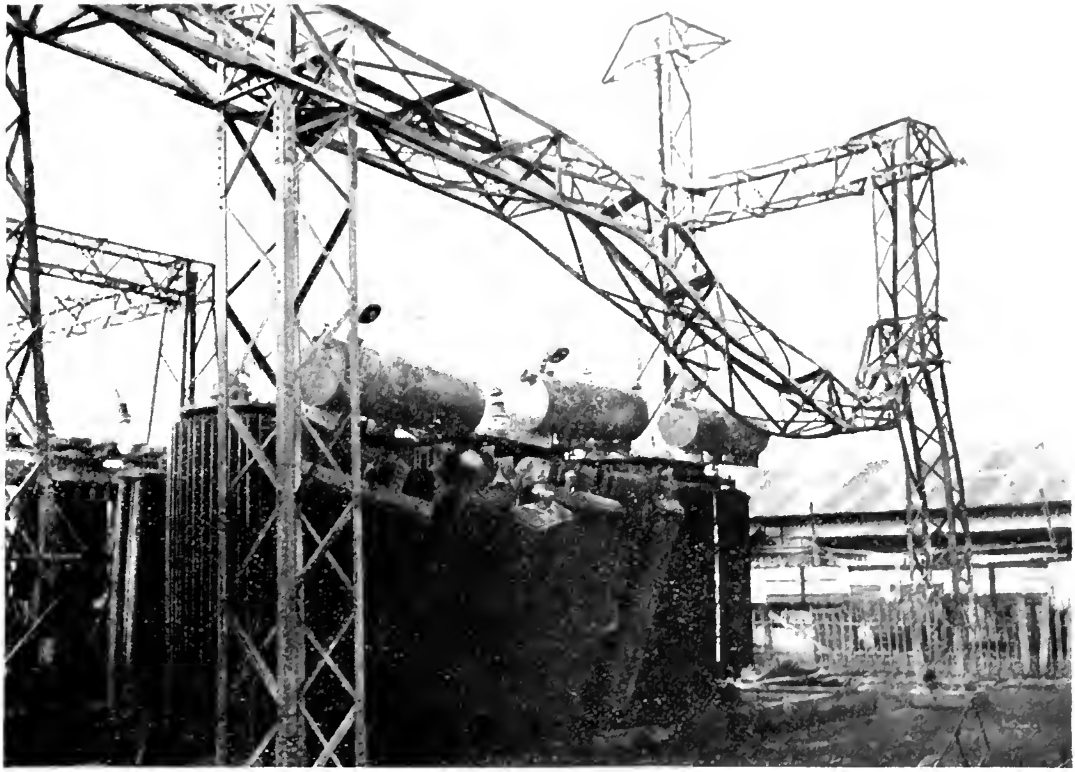

Photo 3—Chigasaki substation Transformer bank No 1 exploded when struck by 50-cal incendiary bullet

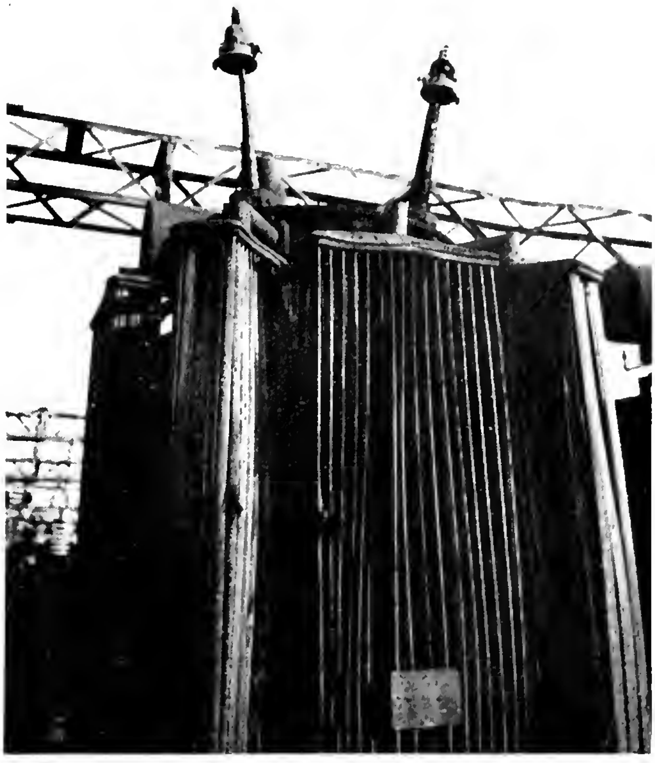

Photo 4—Chigasaki substation—Transformer destroyed by fire. Note 50-cal penetration through radiators

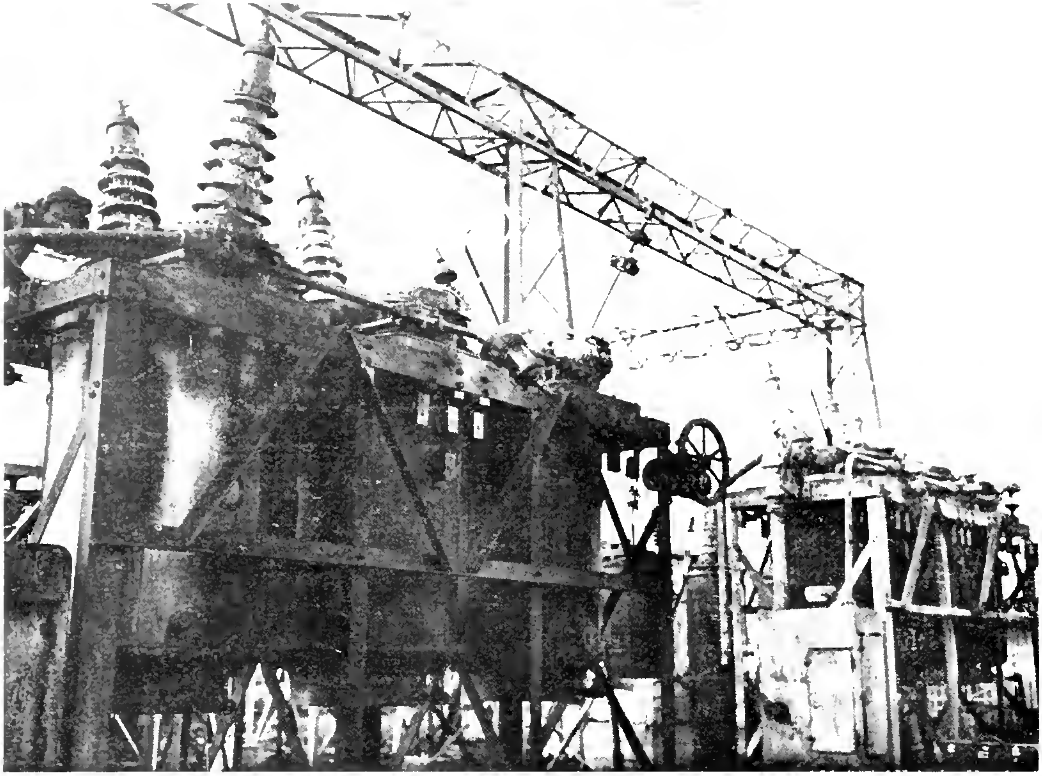

Photo 5—Chigasaki substation—Two banks of 154-KV OCB destroyed by fire. 50-cal incendiary hit on bushing

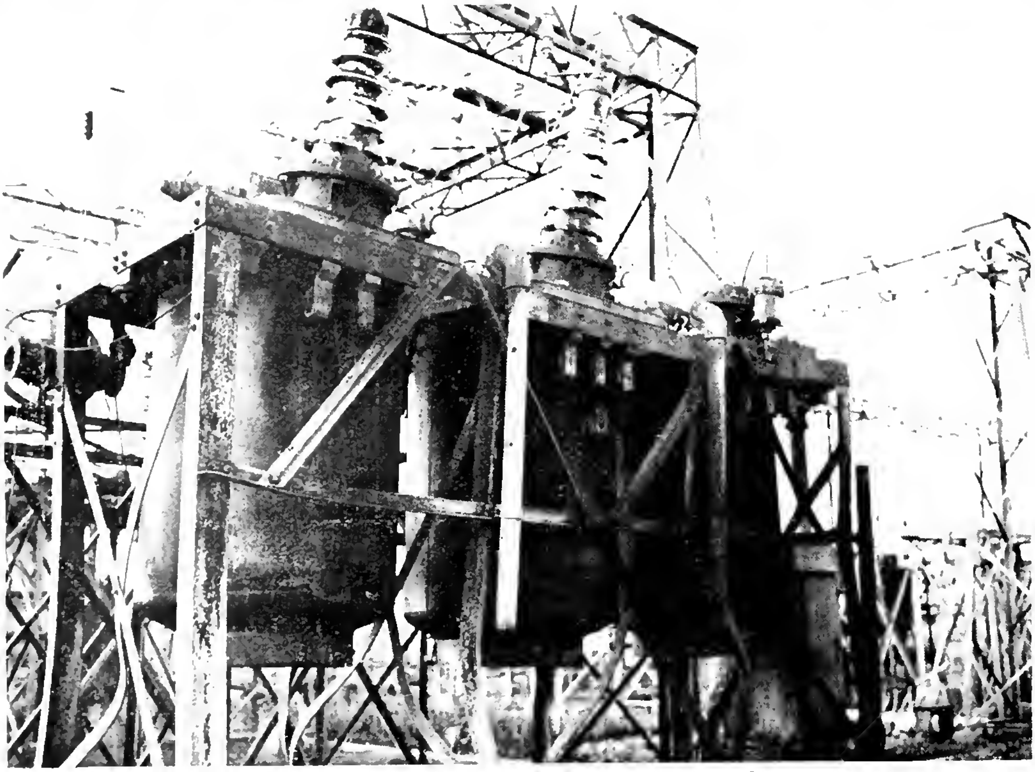

Photo 6—Chigasaki substation—154-KV OCB destroyed by fire

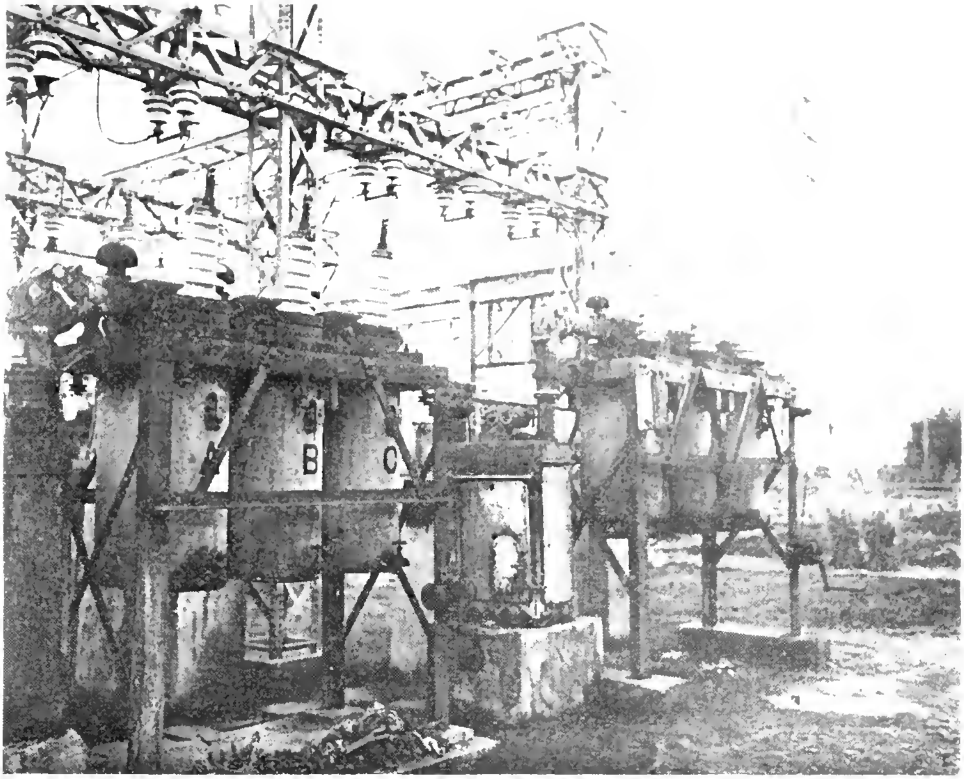

Photo 7—Chigasaki substation—22-KV OCB damaged by fire

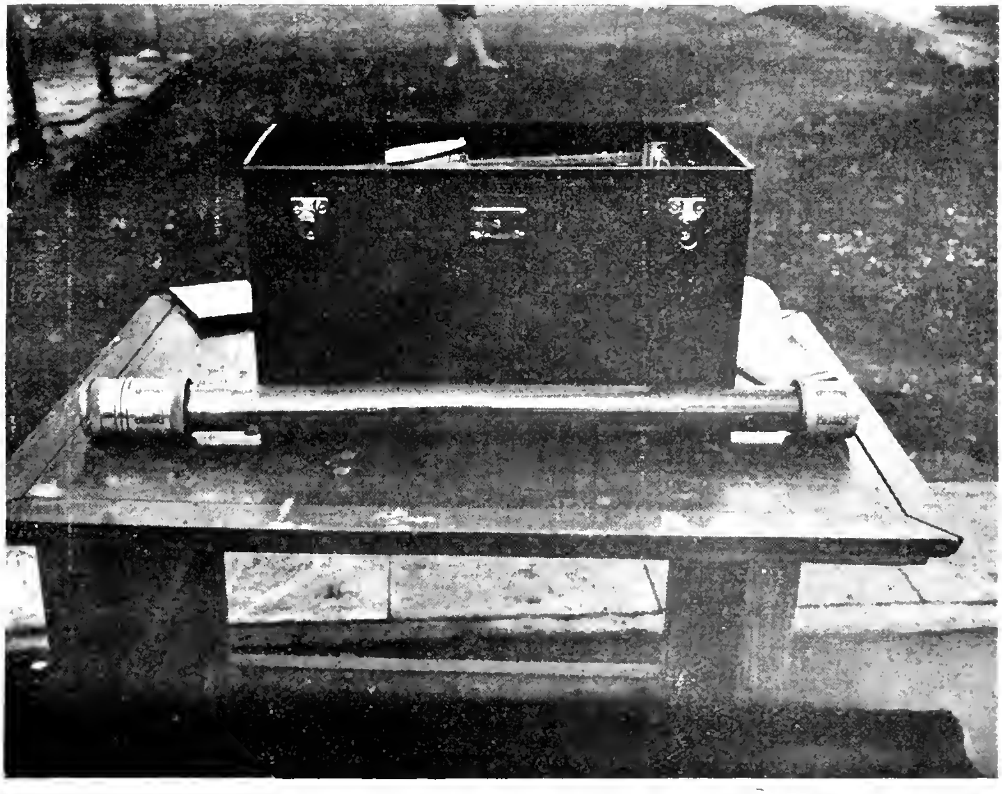

Photo 8—Chigasaki substation—Japanese copy of American manufactured liquid high voltage fuse

Photo 9—Hachioji substation—Area around the substation

Photo 10—Hachioji substation—Area around station showing crowded, inflammable buildings. Buildings shown have been built since the area was destroyed by fire on 2 August 1945

Photo 11—Honginchо substation—View showing metal window shutters installed to protect against fires during earthquake

Photo 12—Jukkengawa substation—Front view of building—transformer room in foreground—spare transformers, stored in yard, also destroyed

Photo 13—Jukkengawa substation—rear view of building, transformer room on right

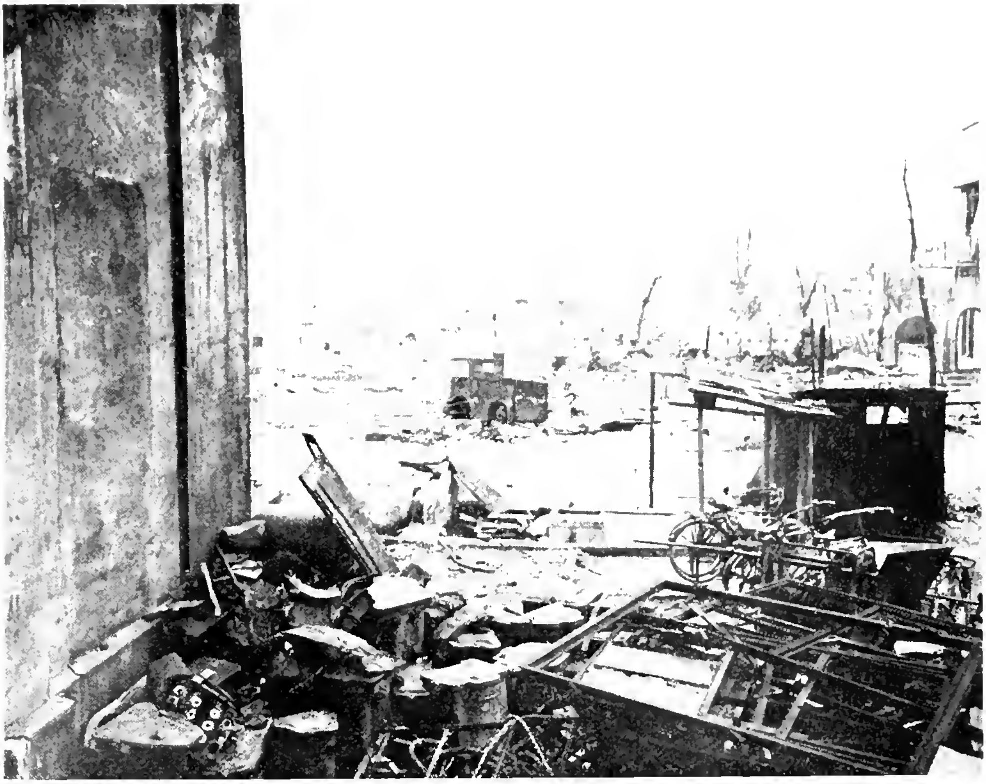

Photo 14—Kojimachi substation—General view of surrounding territory showing complete destruction. Diet Building in center background

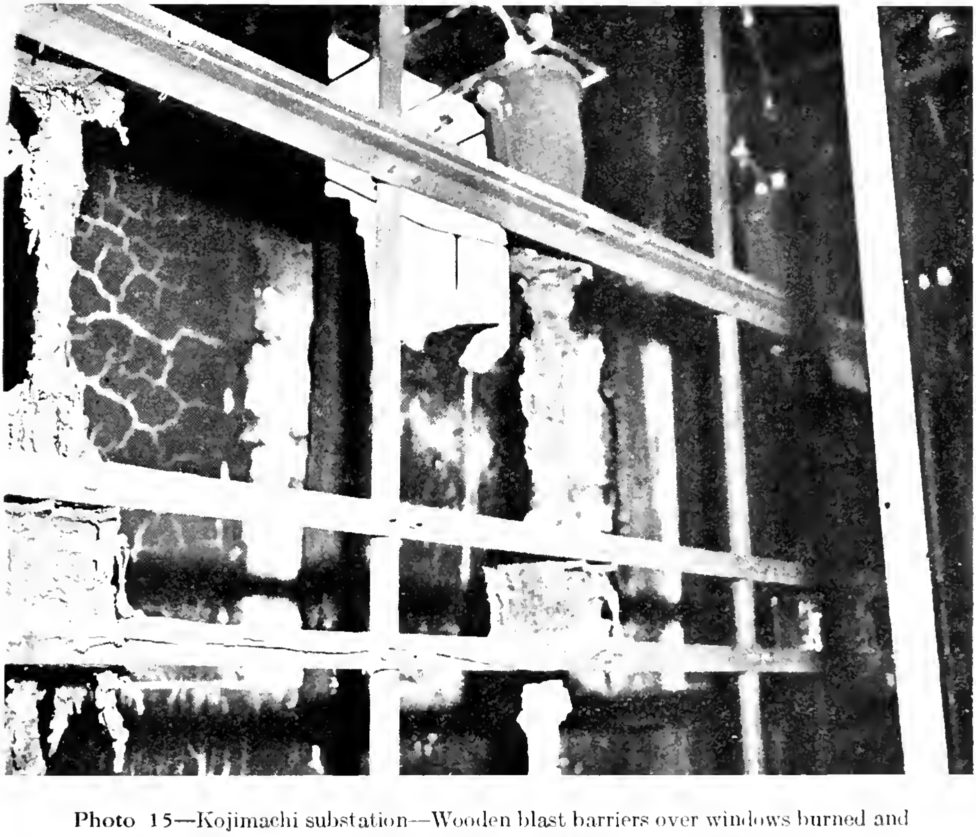

Photo 15—Kojimachi substation—Wooden blast barriers over windows burned and damaged cable entrances

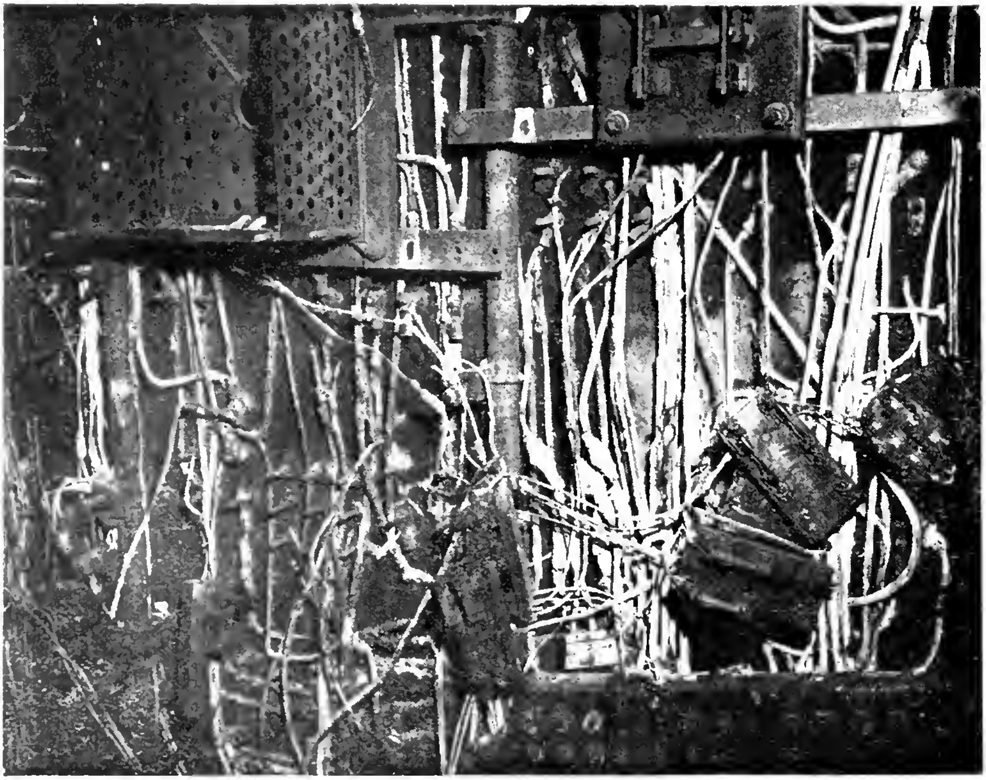

Photo 16—Kojimachi Substation—Rear view of switchboard which was located on second floor

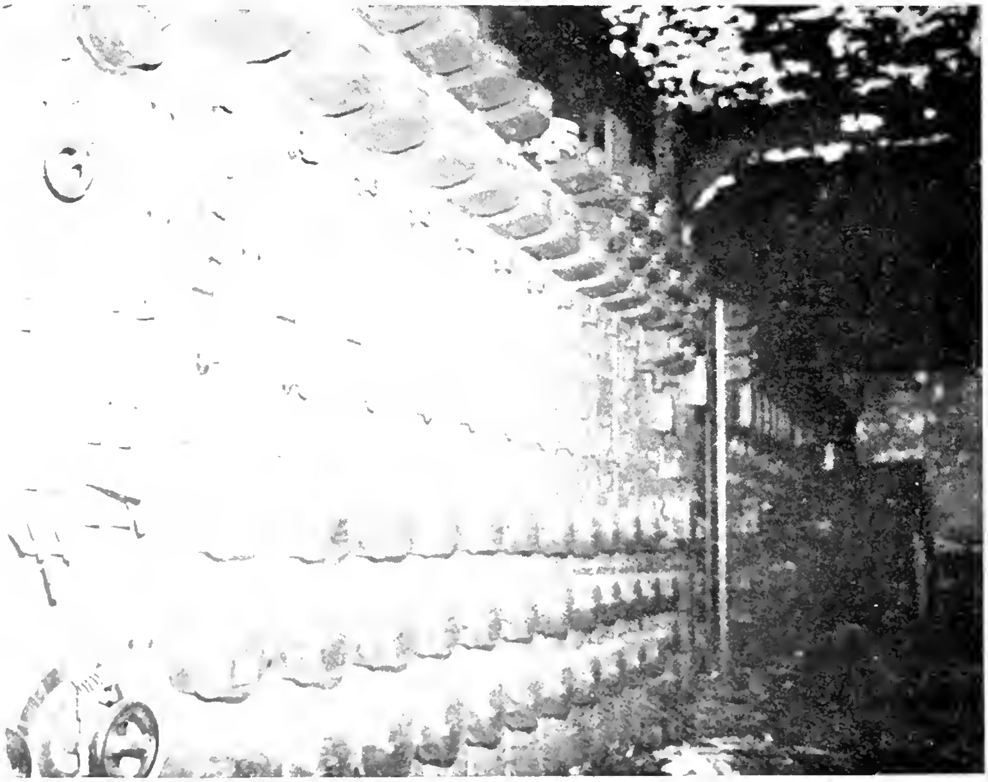

Photo 17—Kojimachi Substation—Front view of switchboard which was located on second floor

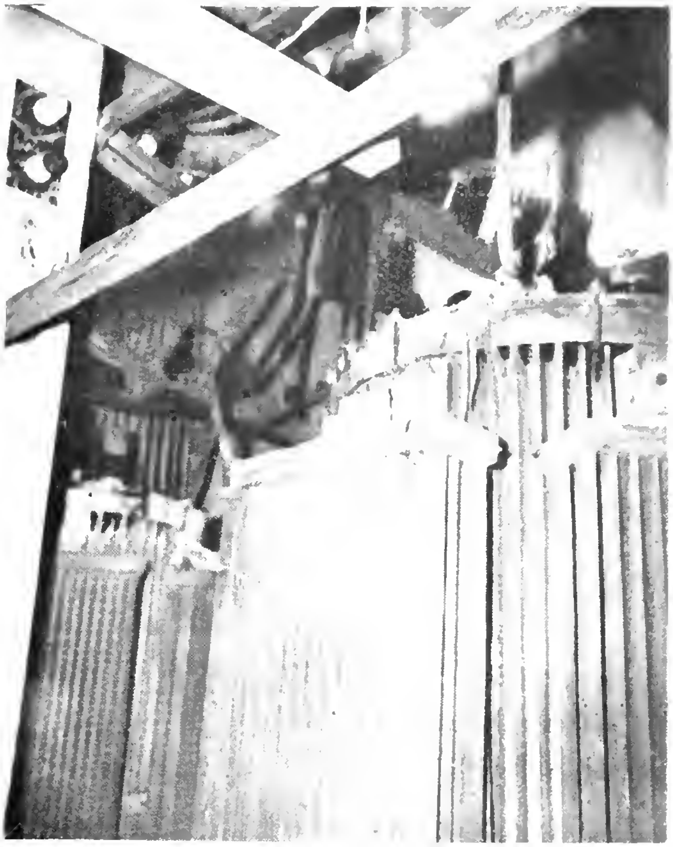

Photo 18—Kojimachi substation—Transformer and bus structure damage on first floor

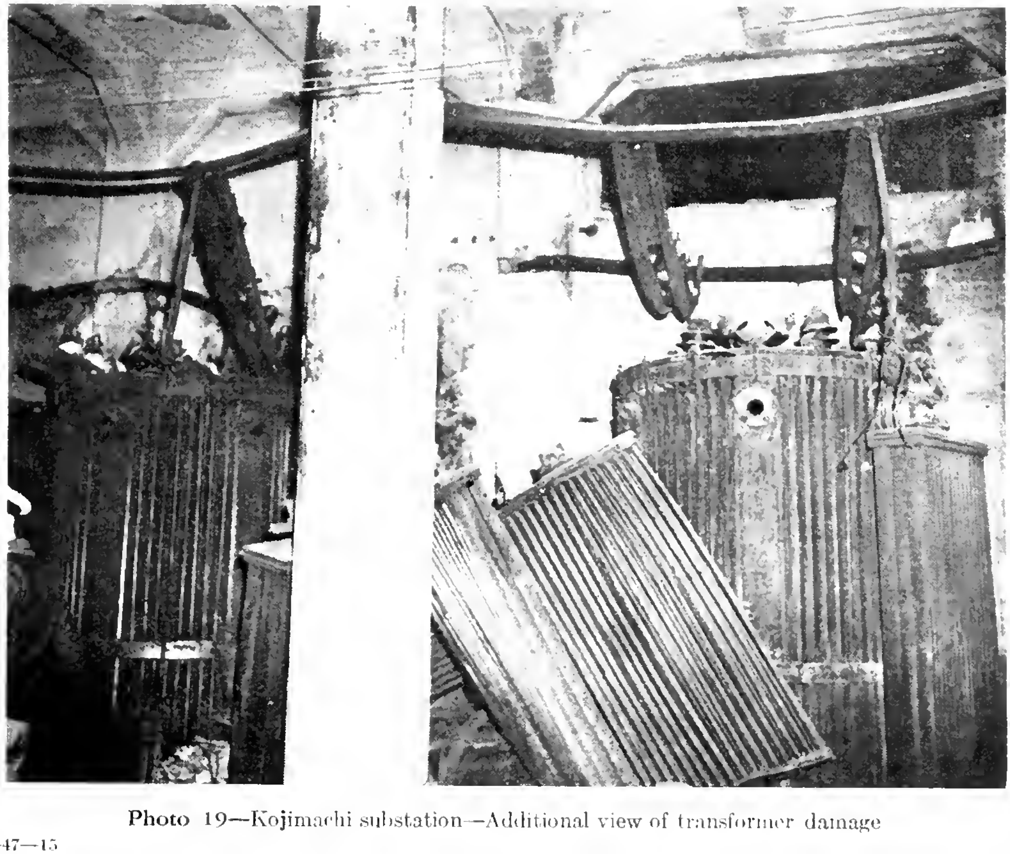

Photo 19—Kojimachi substation—Additional view of transformer damage

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Photo 20—Kojimachi substation—Three-phase 3.3 KV bus voltage regulator. Located on first floor in separate room

Photo 21—Nippori substation—General view of station. Incendiary bomb penetrated roof in center foreground

Photo 22—Nippori substation—View from inside switch room, second floor, to show hole in roof made by bomb

Photo 23—Oshima substation—General view of property showing building construction to protect against fires during earthquakes

Photo 24—Oshima substation—View of mark on concrete tile roof made by incendiary bomb. Empty incendiary case for comparison

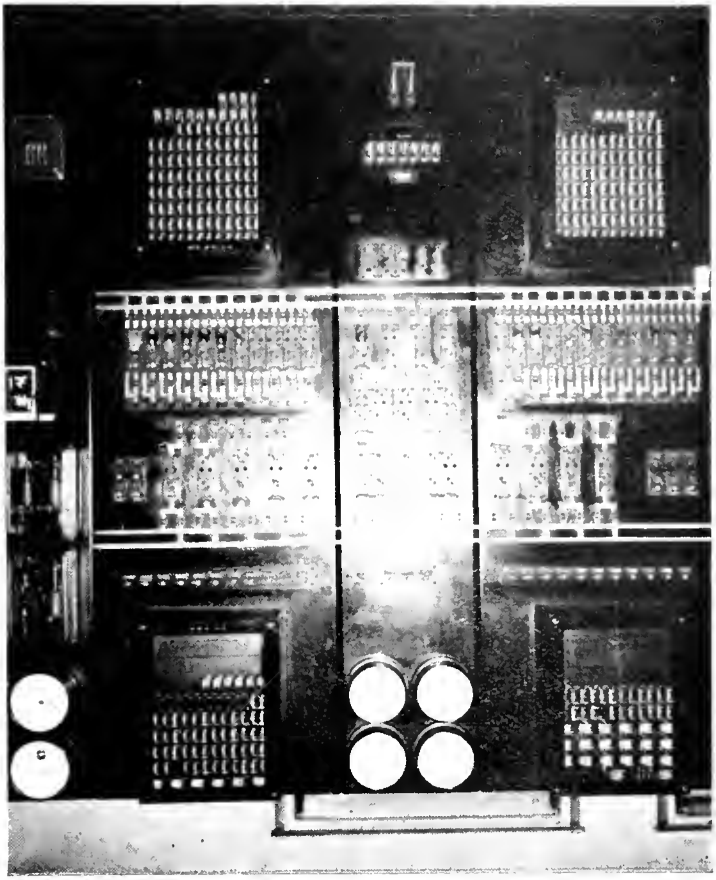

Photo 25—Oshima substation—Supervisory control board for remote control of Sunamachi substation

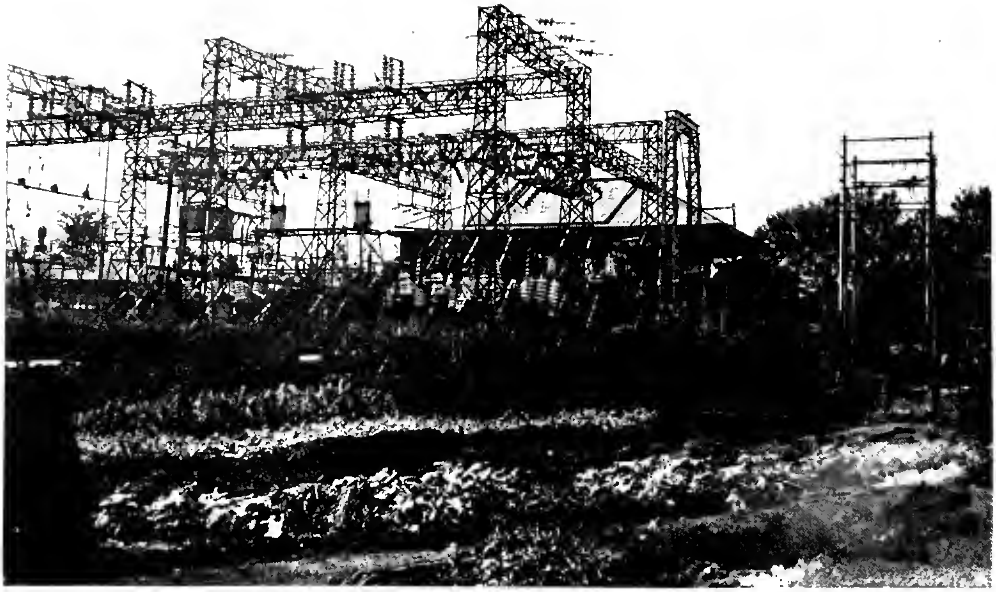

Photo 26—Ozaku substation—General view of station from back, showing destroyed transformer in right background

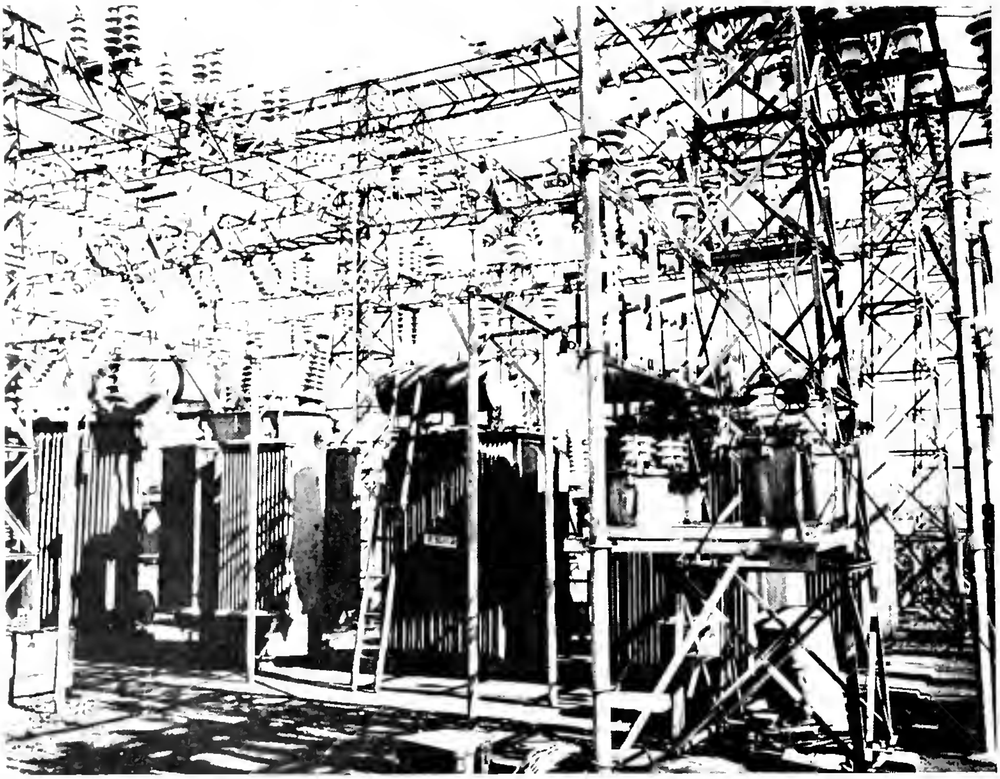

Photo 27—Ozaku substation—View inside the switching structure

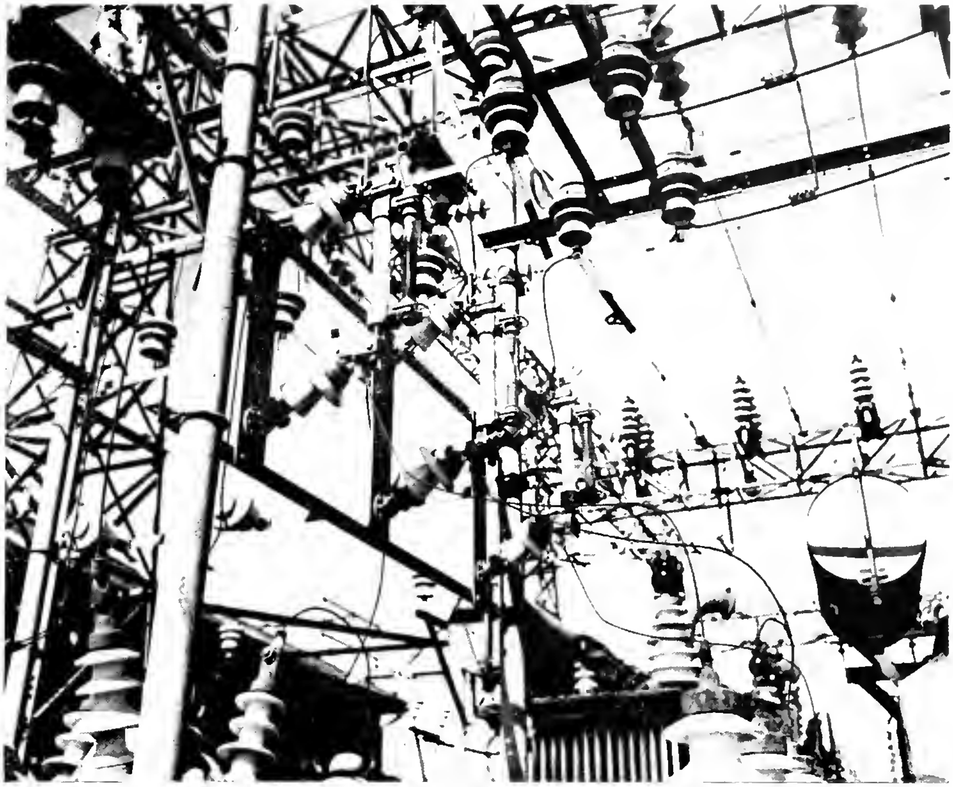

Photo 28—Ozaku substation—Japanese copy of familiar American liquid fuse

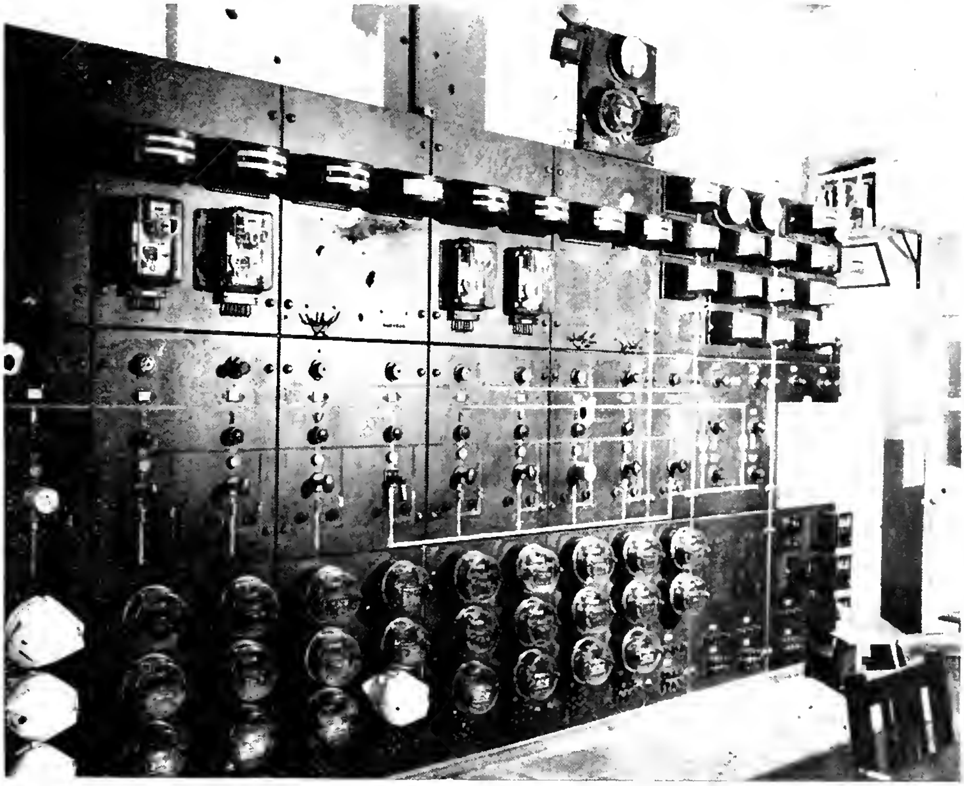

Photo 29—Ozaku substation—Front view of switchboard showing 50-cal penetrations

Photo 30—Ozaku substation—Example of welding repairs to transformer tank penetrated by 50-cal bullets. No fire had occurred

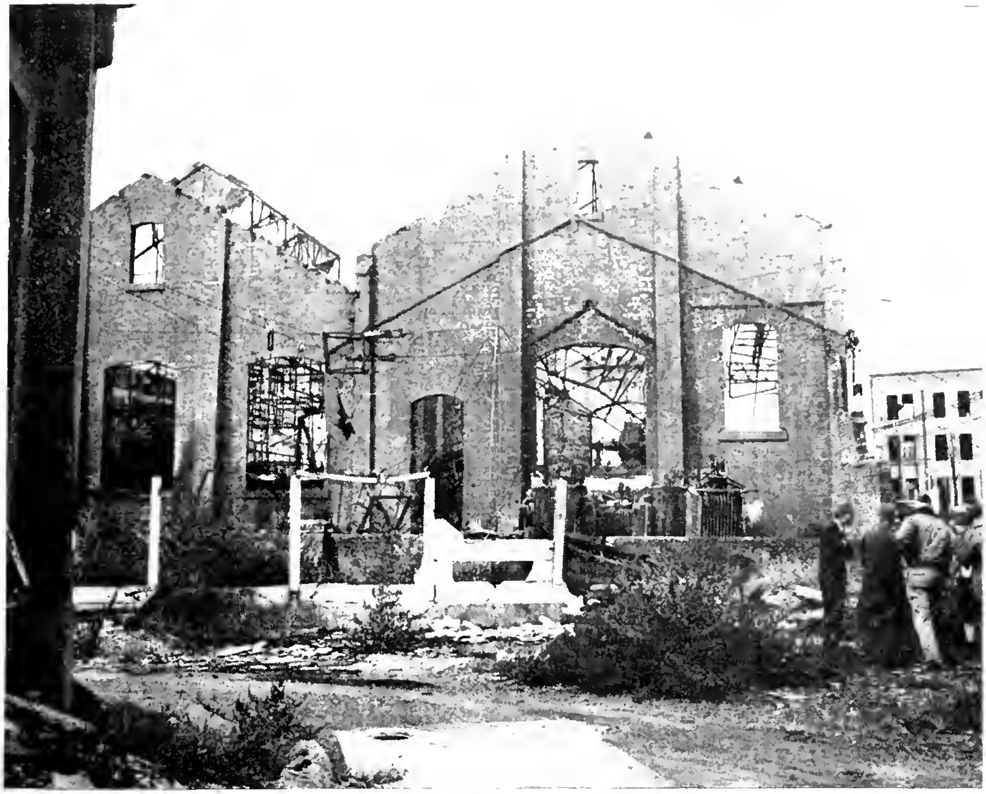

Photo 31—Sugamo substation—Front view of building—transformer and regulator storage yard in foreground

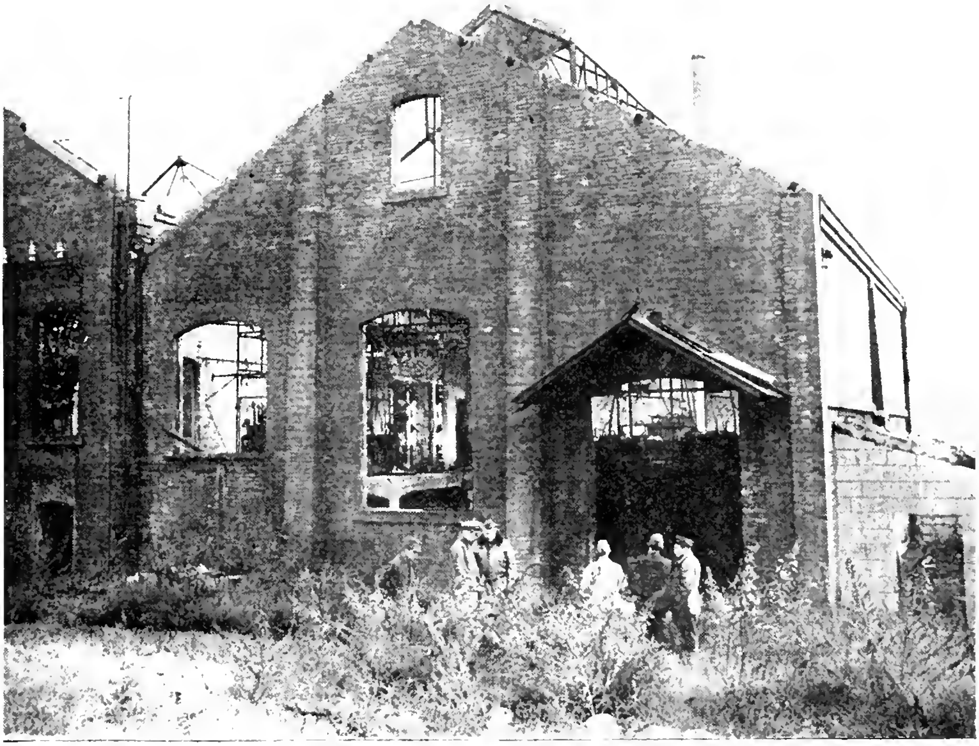

Photo 32—Sugamo substation—Rear view of building. Transformers and switchboard showing are completely destroyed

Photo 33—Sugamo substation—Rear corner of building where HE bomb hit

UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Those reports marked with an asterisk (*) may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

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*1 The United States Strategic Bombing Survey: Summary Report (European War)
*2 The United States Strategic Bombing Survey: Over-all Report (European War)
*3 The Effects of Strategic Bombing on the German War Economy

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8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
10 Focke Wulf Aircraft Plant, Bremen, Germany
11 Messerschmitt A G, Augsburg, Germany — Over-all Report; Part A; Part B; Appendices I, II, III
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16 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
18 Bayerische Motorenwerke A G (BMW) Munich, Germany
19 Henschel Flugmotorenwerke, Kassel, Germany

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23 Aluminiumwerk G m b H, Plant No. 2, Bitterfeld, Germany
24 Gebrueder Giulini G m b H, Ludwigshafen, Germany
25 Luftschiffbau, Zeppelin G m b H, Friedrichshafen on Bodensee, Germany
26 Wieland Werke A G, Ulm, Germany
27 Rudolph Rautenbach Leichmetallgiessereien, Solingen, Germany
28 Lippewerke Vereinigte Aluminiumwerke A G, Lunen, Germany
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30 Duerener Metallwerke A G, Duren Wittenau-Berlin & Waren, Germany

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39 A Brief Study of the Effects of Area Bombing on Berlin, Augsburg, Bochum, Leipzig, Hagen, Dortmund, Oberhausen, Schweinfurt, and Bremen

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46 Augsburg Field Report
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*50 Optical and Precision Instrument Industry Report

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52 Mayer and Schmidt, Offenbach on Main, Germany

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*53 The German Anti-Friction Bearings Industry

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*54 Machine Tools & Machinery as Capital Equipment
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58 Naxos Union, Frankfort on Main, Germany

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70 Neunkirchen Eisenwerke A G, Neunkirchen, Germany
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